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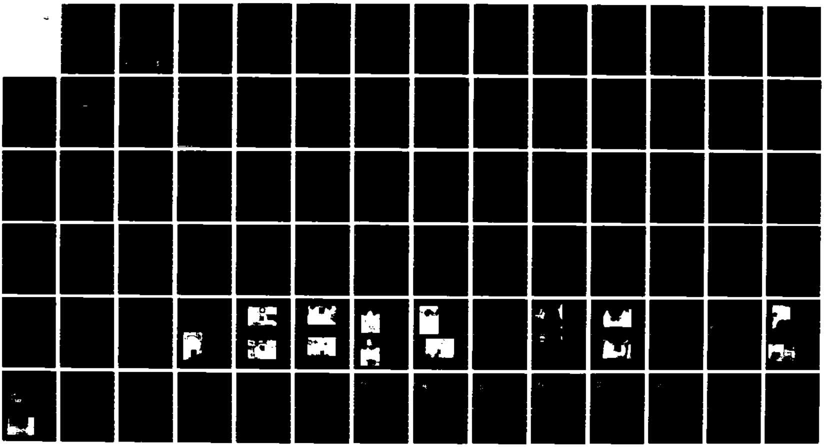

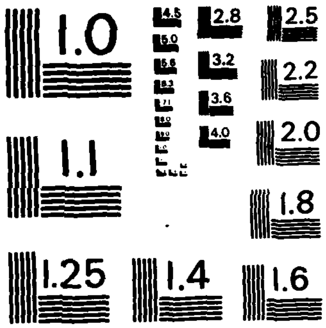

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IMPROVED LOW TEMPERATURE CHARACTERISTICS 500 GALLON COLLAPSIBLE FUEL DRUM

FINAL TECHNICAL REPORT
by

D. V. Perkins
R. E. Dorsch, P.E.

ENGINEERED SYSTEMS DEPARTMENT

January 1984

U. S. ARMY BELVOIR R & D CENTER
FORT BELVOIR, VIRGINIA 22060

Prepared by
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Mishawaka, Indiana 46544

Contract Number DAAK70-82-C-0115

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Uniroyal has developed a 500 gal. collapsible fuel drum manufactured and tested in accordance with Mil-D-23119E, NSN 8110-00-824-1444, having improved low temperature operational characteristics for use under arctic conditions to -60°F (-51°C). A promising construction has been identified for arctic fuel hose.

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SUMMARY

This report describes the development of a 500 gal. collapsible fuel drum manufactured in accordance with Mil-D-23119E, (NSN 8110-00-824-1444), having improved operational characteristics at low temperatures for use under artic conditions. The goal of this contract was to produce drums having an operational temperature of -60°F (-51°C).

To achieve this goal, Uniroyal performed a work effort consisting of two phases. Phase I consisted of:

1. Defining the low temperature properties of the existing fuel drum.

2. Evaluation of three proposed liner materials, four tread stock materials and three cord reinforcement materials for improved low temperature performance.

3. Evaluation and modification of hardware components for use at -60°F.

4. Selection of two candidate constructions for fabrication of 500S fuel drums to be listed in Phase II.

Phase II was to consist of the fabrication of ten 500S containers, five from each of the two constructions decided upon at the end of Phase I. These constructions were to have been:

1. "J" construction consisting of a Polypropylene Oxide tread and carcass stock having a millable Polyurethane liner and using a Polyester cord reinforcement.

2. "D" construction consisting of a Polypropylene Oxide tread and carcass stock having a Polysulfide liner and Polyester cord reinforcement.

Five "J" construction drums were successfully fabricated and tested as outlined in Mil-D-23119E with the exception of the deceleration test. This construction exceeded the performance testing requirements of Mil-D-23119E and performed exceptionally well at -60°F (-51°C). Five "J" construction drums were delivered to the Army for arctic field trials. Severe manufacturing problems were encountered in fabrication of the "D" construction drums. A total of 5 units were fabricated with none of them resulting in a testable item. At this time, Uniroyal proposed:

1. Two prototype drums fabricated early in the contract be shipped as part of the contract requirement. These drums consisted of an "A" construction drum having a Polypropylene Oxide tread carcass and liner using a Polyester cord reinforcement and a "F" construction drum having a millable Polyurethane tread carcass and liner using a Nylon tire cord reinforcement.

2. Since material was available, Uniroyal would produce seven lengths of 5 ft. long - 2" diameter hose of the "D" construction so that this construction, as a fuel containment system, could be evaluated under arctic conditions.

These proposals were accepted and the two 500S drums and the seven lengths of hose were shipped to the Army for field evaluations.

PREFACE

The work described in this report was accomplished for the U. S. Army Belvoir R & D Center under Contract Number DAAK70-82-C-0115 and was performed by the Engineered Systems Department of Uniroyal. All project management, design functions and unit fabrication were accomplished at Uniroyal's Mishawaka, Indiana facilities. All material and drum assembly testing was done at Uniroyal's Mishawaka Plant or Uniroyal's Currant Rd. test facility, also located in Mishawaka, with the exception of the low temperature modulus determinations which were performed at Cincinnati Testing Laboratories located in Cincinnati, Ohio under the direction of Mr. D. Browning and Mr. G. Huber.

The project was initiated in June of 1982 and completed in December 1983. Field trial performance testing of the experimental units will be conducted by the Army through the winter of 1983-1984 under arctic conditions.

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1.0 Introduction

1.1 This report describes the results of the work effort performed under Contract DAAK70-82-C-0115 entitled "Improved Low Temperature Characteristics - 500 Gallon Collapsible Fuel Drum. This effort was accomplished to improve the operational characteristics of the 500S Fuel Drum (NSN 8110-00-824-1444) between -30°F (-34°C) and -60°F (-51°C). The requirements as described in Mil-D-23119E were used as desired guidelines recognizing that some of the current drum properties might have to be sacrificed to achieve the desired low temperature performance.

Uniroyal's effort was directed towards accomplishing the stated objectives through a two Phase effort detailed below.

Phase I - Performance evaluation of existing and candidate drum materials at low temperatures.

- Task I - The study of existing drum construction components' characteristics at low temperature extremes.
- Task II - The study of proposed drum construction components' characteristics at low temperature extremes.
- Task III - Evaluation of candidate composite constructions for improved performance at low temperature extremes.
- Task IV - Improved hardware design.

Phase II - Improved low temperature drum fabrication and testing.

- Task I - Drum Fabrication.
- Task II - Drum Testing - per preproduction test schedule of Mil-D-23119E.
- Task III - Drum Disposition - Shipment of drums for Army field testing.

The scope of this report includes all work performed under Phase I and Phase II as outlined above. Recommendations are made for future efforts which were outside the scope of this contract.

2.0 Investigation and Discussion

2.1 Performance Evaluation of Existing Drum Construction Components At Low Temperature Extremes - Phase I, Task I

2.1.1 Tread Liner and Carcass Gum Testing

Samples of the existing drum tread (3130), carcass (3139) and liner (3132) gums were molded into ASTM slabs (6" x 6" x .080" and tested per ASTM D2137 for low temperature brittleness. One set of original samples and one set of samples treated as follows were tested.

> Condition samples in ASTM Reference fuel D @ 73°F ± 2°F for 4 days. Remove samples from fuel and condition them for 2 days at 73°F ± 2°F. Oven age samples in air for 24 hrs. at 130°F ± 2°F.

The results of these tests are shown in Table I. The data is presented with the data for the Phase I, Task II compounds for comparison purposes, which will be discussed in detail under 2.2.1.

The data indicates rather poor performance of all but the tread compound on the unaged samples and equally poor performance of the carcass and liner compounds after fuel soaking, with poorer performance being demonstrated by the tread compound after the aging. This would indicate poorer low temperature performance might be expected from the existing drum after repeated field use.

The following samples were fabricated for modulus of elasticity and flexural strength testing at 0°F, -30°F, -40°F, -50°F and -60°F in accordance with ASTM D790 Method II, Procedure B.

Samples of the existing tread gum (3130), carcass gum (3139) and liner gum (3132) were molded into ¼" thick slabs. One half of this sample set was fuel aged and conditioned using the same procedure as outlined for the ASTM D2137 testing. One half inch wide by 5" long samples were cut from the aged and unaged samples.

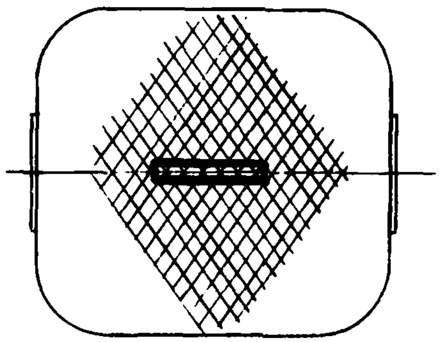
Sample testing was performed by Cincinnati Testing Laboratories. The data is shown in Tables II, III, IV and V and represents the average of 3 test values. The samples were conditioned one hour at the test temperature.

These results are presented with the data for Phase I, Task II compounds for comparison purposes, which will be discussed in detail under 2.2.1.

2.1.2 Existing Drum Composite Testing

Samples of the existing drum composite construction were fabricated for modulus of elasticity testing at 0°F, -30°F, -40°F, -50°F and -60°F in accordance with ASTM D790 Method II, Procedure B. One half of this sample set was fuel aged (liner side only) and conditioned using the same procedure as outlined for the ASTM D2137 testing; ½" x 5" long samples were cut from the aged and unaged samples according to Figure 1 which resulted in all cord orientation being the same between samples and sample sets.

Figure 1



Sample position is shown relative to drum reinforcement orientation, however, actual samples tested were cut from 24" x 24" hand fabricated panels.

The sample testing was performed by *Cincinnati Testing Laboratories*. The data is presented in Table VI. All sample conditioning times are 60 min. unless otherwise noted.

These results are presented with the composite data from Phase I, Task III for comparison purposes, which will be discussed in detail under 2.3.5.

2.1.3 Rayon Cord Reinforcement Testing

Stress/strain curves were run for the existing Rayon cord reinforcement at 70°F, -30°F, -40°F, -50°F and -60°F in accordance with ASTM D2256 and ASTM D832. The results of this testing along with other data on the Rayon cord reinforcement is presented in Table VII. The data for the candidate cord materials from Phase I, Task III is also included for comparison purposes and will be discussed in detail under 2.2.2.

2.1.4 Analysis of Existing Component Hardware Performance at Low Temperatures

The functional performance testing of a Uniroyal standard hardware assembly for 500S fuel containers was performed at -60°F after 3½-4 hours of conditioning. Both the swivel plate and shackle assemblies performed well at the -60°F temperature.

Analysis of the material components in the end plate assemblies revealed that all alloy components should perform adequately at -60°F with the possible exception of the swivel plate which is a cast pearlitic ductile iron. This material does display a major change in Charpy impact value at -60°F, which could cause fracture if this component is subjected to severe impact at -60°F temperatures.

After conditioning a 2" dia. adapter valve used on the Uniroyal Sealdrum and an OPW cam lock coupler valve assembly at -60°F for approximately 4 hours, an attempt was made to assemble the two. It was found that the cam locks on the coupler could not be closed at this temperature. Examination of both components disclosed that a rubber washer in the coupler could not be compressed at this temperature which prevented the cam locks from closing.

Information was received from our vendor who manufactures the 3/8" dia. 7 x 19 stainless steel cable assemblies used in the Uniroyal Sealdrums. The data received indicates that the cable is manufactured under specification Mil-W-83420 which is a control cable specification for aircraft. This specification requires that the 3/8" dia. cable be fatigue tested over a 3½" dia. pulley and run for 120,000 reversals at -65°F. After this test, the cable must possess a minimum of 60% of its original strength. It, therefore, appears that the flexing of the cable during drum evacuation at -60°F will not be detremental to the cable from a strength standpoint.

Low temperature testing of the cable construction at Cincinnati Testing Laboratories was accomplished. Data is presented in Table VIII. There is no significant increase in apparent modulus going from room temperature (74°F) to -60°F. The cable was conditioned for 60 minutes at -60°F prior to testing.

A standard Uniroyal Military Sealdrum (500S) which contained the cables was filled with 485 gallons of water. It was then pumped out removing as much water as possible leaving the unit attached to the pump and allowing a high suction to develop. The drum was then raised with a hoist and drained until empty with the retained gallonage recorded as 1.59 gallons. The cables were removed and the above procedure repeated. It was found that a drum which contained cables retained only two-tenths of a gallon more than one without cables.

2.1.5 Analysis of Each Existing Drum Component and Its Effect on Low Temperature Performance

Three areas were analyzed for contribution to the drums performance at low temperature, 1) existing gum compounds, 2) cord reinforcement and 3) drum hardware.

The data obtained for the modulus of elasticity and flexural modulus testing at low temperature of the existing drum tread carcass and liner gums provides the most dramatic evidence of reduced performance with decreasing temperatures.

As can be seen from the data in Tables II, III, IV and V, the modulus of elasticity increases from 100 to 300 times for the existing drum elastomer compounds from $0^{o}F$ to $-60^{o}F$. The flexural strength increase at $-60^{o}F$ is less dramatic, at from 25 to 80 times the value at $0^{o}F$, but still is significant.

The test data obtained for the cord reinforcement (Table VII) shows only a modest increase of Tensile modulus from $0^{o}F$ to $-60^{o}F$ indicating its contribution to increased construction stiffness at low temperatures is minor.

The results of the hardware testing indicate little interference in filling and emptying from the cable assembly.

Gaskets, Part #MS27030-5 and MS27030-6 in coupler valve assembly, must be replaced with gaskets made of a material possessing better low temperature compression characteristics if this valve assembly is to be coupled at temperatures below $-30^{o}F$. This problem was addressed and the solution is detailed in section 2.4.

2.2 Performance Evaluation of Proposed Drum Construction Components Characteristics at Low Temperature Extremes - Phase I, Task II

2.2.1 Candidate Gum Compound Evaluation and Testing

The following materials for liner and tread gums were initially considered for improvement of low temperature properties.

Liner Materials

- Polysulfides
- Fluorosilicone
- Polyurethane (Millable Gums)

Tread Materials

- Polypropylene Oxide
- Polysulfide
- Fluorosilicones
- Polyurethane (Millable Gums)

To minimize the construction complexity, it was proposed that the cord (carcass) gum be made from a suitable tread or liner material.

A literature search was conducted and vendors contacted to obtain compounds from each candidate group which would exhibit superior low temperature properties with fuel resistance being the secondary concern.

This work resulted in the eight compounds listed in Table IX for evaluation in the Phase I, Task II effort.

Physical properties of Phase I, Task II compounds were determined and are presented in Table X. All properties appeared to be at acceptable levels with the possible exception of the relatively low tensiles obtained on the polysulfide compounds, 101913A and B, and the Fluorosilicone compound 101914. Major difficulties arose in mixing and handling the Fluorosilicone compound (101914). It became apparent that a scraper bar would be required for mill mixing of this material. Since eventual factory mixing of this material would be required, it was dropped from consideration due to factory equipment mixing limitations.

Low temperature brittleness tests according to ASTM D2137 were run on Phase I, Task II compounds. The data is presented in Table I of this report. Both Polypropylene Oxide compounds (101910A and B) and the Adiprene CM compound 101912A passed the -60°F test both before and after fuel soak. The Millathane samples showed generally poor performance. The Polysulfide FA material showed poor performance both before and after fuel soak. The Polysulfide ST compound showed good performance to -60°F before fuel soak but poorer performance (cracked @ -50°F) after fuel soak.

Samples of candidate gum liner and tread materials (Phase I, Task II compounds) were tested at Cincinnati Testing Laboratory in accordance with ASTM D790, Method II, Procedure B. The results of these tests are reported in Tables II, III, IV and V. The data for the existing drum tread liner and cord (carcass) gums is presented for comparison purposes.

All Phase I, Task II compounds with the exception of the Millathane 76 compound performed better than the best existing container gum.

The best low temperature performer was the Polypropylene Oxide compound 101910A, followed by the Polysulfide ST compound, 101913B. The next two best performers were the Adiprene CM compound 101912A and the Polysulfide FA compound, 101913A. The worst performer of these four shows a 3-4 fold improvement over the best existing gum compound (3130 tread).

In an effort to determine the relative fuel resistance of the candidate materials, % volume swell and % weight change tests were run on the three existing drum compounds and on the top three candidate materials. The samples were immersed 4 days at room temperature in ASTM Fuel D. The results of these tests are shown in Figure 2.

Figure 2

	% Change Volume	Weight
Tread - 3130	+ 65.8	+ 38.4
Carcass - 3139	+ 23.1	+ 10.3
Liner - 3132	+ 23.9	+ 14.4
101910A (Polypropylene Oxide)	+ 55.3	+ 39.3
101912A (Millable Urethane)	+ 30.7	+ 19.6
191913B (Polysulfide ST)	+ 11.5	+ 6.2

These results indicate the proposed materials have no higher swell than the poorest performer (3130 tread gum) of the existing drum construction. The data also suggests that the 101910A Polypropylene Oxide compound should be utilized as a tread and carcass gum candidate but not a liner compound due to its relatively high swell characteristics.

Tabor abrasion testing was done on the existing tread compound (3130) and on two of the top three low temperature performers, the 101910A Polypropylene Oxide compound and the 101912A Adiprene CM compound. This test was run to determine suitability of these compounds as an outer cover (tread) compound. The results of these tests are shown in Figure 3 below.

Figure 3

Tabor Abrasion (H18 Wheel, 70 RPM, 1000g Load)
% Wt. Loss

	100 Cycles	200 Cycles	300 Cycles
Standard 500S tread compound	.032	.045	.049
101910A Polypropylene Oxide compound	.002	.007	.008
101912A Adiprene CM compound	.016	.020	.032

The results of these tests show better performance of each of the candidate compounds over the 3130 control compound. The 101913B Polysulfide compound was excluded from consideration as a tread compound due to its low physical properties.

2.2.2 Candidate Reinforcement Material Evaluation

A search was conducted for Nylon, Polyester and Kevlar tire cord constructions which could be utilized in fabrication of an improved drum construction. The criteria desired in each of the tire cord constructions was to achieve the same or similar per-inch breaking strengths or in the case of the Kevlar, be able to develop a 2-ply construction making use of its greater strength to weight ratio.

An 840 denier 2-ply 22.6 ends-per-inch Nylon tire cord, Style 7700-23, and a 1000 denier, 2-ply, 22.4 ends-per-inch Polyester tire cord, Style 2311-12, were found. These tire cords closely approximate the strength characteristics of the current Rayon cord material. The basic characteristics of these tire cord materials are shown in Table VII of this report.

Two Kevlar type T956 cord constructions were available from DuPont. Their basic strength characteristics are detailed in Table VII. No commercially available cords are being produced which are of the same end breaking strength as the other three materials. The 1500 denier/1 ply material at 23 ends-per-inch would lend itself to a possible 2-ply drum construction. The 1500 denier/2-ply construction at 12 ends-per-inch would theoretically apply to a 4 ply fuel drum construction; however, with the wide spacing of the cord, the tire cord fabric would pose severe spreading, calendering and fabrication difficulties.

Tensile modulus determinations were made on candidate materials at 70°F, -30°F, -40°F, -50°F and -60°F according to a test procedure outlined in Appendix 1 of this reports.

The results of these tests indicate Rayon cord has the lowest tensile modulus at -60°F followed by Nylon, then Polyester and, finally, Kevlar. The Kevlar cord shows very high tensile modulus at all temperatures.

The increase in tensile modulus for all materials from 70°F to -60°F was slight with Kevlar showing little or no increase.

2.2.3 Relative Rigidity Calculations (See Appendix IV)

Upon completion of the testing under Phase I, Task II, it was felt that prior to choosing the cord reinforcements to be used in the composite panel fabrication and testing in Phase I, Task II that the trade-off between decreased composite thickness and reinforcement modulus should be investigated since each cord reinforcement material has a different thickness and would result in a different composite thickness.

The following seven (7) theoretical composites were evaluated using a mathematical model (see Appendix #2 for derivations of this model).

2 ply Kevlar 1500/1
1 ply Kevlar 1500/2
4 ply Kevlar 1500/1
4 ply Kevlar 1500/2
4 ply Nylon 840/2
4 ply Rayon 1650/2
4 ply Polyester 1000/2

The following assumptions were made in the calculations:

a. Polypropylene Oxide compound #101910A was used as the liner carcass and tread gum in all cases.

b. Thicknesses used for tread, carcass and liner gums covering cord are those in use in current production drums.

c. The only 2 ply construction possible was one made from Kevlar cord. All others would sacrifice too many of the current drums' performance characteristics (i.e. puncture and burst strength).

The results of these calculations are shown in Figure 4 below.

Figure 4

Relative Rigidity lbs.-in^2	Order of Preference	Construction
17.45	1	4 ply Nylon 840/2
21.42	2	4 ply Polyester 1000/2
25.55	3	4 ply Rayon 1650/2
24.82	4	2 ply Kevlar 1500/1
25.52	5	2 ply Kevlar 1500/2
138.45	6	4 ply Kevlar 1500/1
157.47	7	4 ply Kevlar 1500/2

2.2.4 Status Meeting Report (Contract Line Item A004)

A meeting was held on January 5, 1983 with Uniroyal personnel and the Contracting Officer's representative to discuss the work performed under Phase I, Tasks I and II and determine the composite constructions to be evaluated in Phase I, Task III.

After review of all the test data, it was agreed to proceed with the 10 constructions in Figure 5 below for Phase I, Task III evaluation.

It was also agreed that samples of two of the best performers from the Phase I, Task III testing would be tested for low temperature properties at the normal 60 minute conditioning and at 240 minutes. This testing will show any crystallinity problems which might not be detectable at the 1 hr. conditioning point.

ASTM slab samples of the three best performers, Polypropylene Oxide (compound #101910A), Adiprene (compound #101912A) and Polysulfide ST (compound #101913B) were supplied to the Contracting Officer's representative for testing at Ft. Belvoir.

Figure 5

A. Solid Polypropylene Oxide (compound #101910A) using a 4 ply Nylon reinforcement.

B. Solid Polypropylene Oxide (compound #101910A) using a 4 ply Polyester reinforcement.

C. Polypropylene Oxide (compound #101910A) with a Polysulfide liner (compound #101913B) using a 4 ply Nylon reinforcement.

D. Polypropylene Oxide (compound #101910A) with a Polysulfide liner (compound #101913B) using a 4 ply Polyester reinforcement.

E. Solid Adiprene (compound #101912A) using a 4 ply Nylon reinforcement.

F. Solid Adiprene (compound #101912A) using a 4 ply Polyester reinforcement.

G. Adiprene (compound #101912A) with a Polysulfide liner (compound #101913B) using a 4 ply Nylon reinforcement.

H. Adiprene (compound #101912A) with a Polysulfide liner (compound #101913B) using a 4 ply Polyester reinforcement.

I. Polypropylene Oxide (compound #101910A) with an Adiprene liner (compound #101912A) using a 4 ply Nylon reinforcement.

J. Polypropylene Oxide (compound #101910A) with an Adiprene liner (compound #101912A) using a 4 ply Polyester reinforcement.

2.3 Performance Evaluation of Proposed Drum Composite Constructions at Low Temperature Extremes (Phase I, Task III)

2.3.1 Candidate Reinforcement Cord to Candidate Elastomer Adhesion Studies

Work was completed for developing cord to gum adhesion systems for two of the three candidate gum materials and two cord reinforcements. NOTE: No system was required for the 101913B (Polysulfide ST) since it was being considered as a liner compound only. The systems evaluated and the peel adhesions obtained are presented in Figure 6 below.

Figure 6

Coating Compound to Cord Adhesion Results

Coating Compound	Nylon Treatment	Nylon Peel #/in.	Polyester Treatment	Polyester Peel #/in. @ 2"/min.
101910A (Polypropylene Oxide)	RFL*	30	RFL	36
101910A (Polypropylene Oxide)	Isocyanate (Uniroyal 3316)	19	Isocyanate (Uniroyal 3316)	**
101912A (Adiprene CM)	RFL	22	RFL	80
101912A (Adiprene CM)	Isocyanate (Uniroyal 3316)	47	Isocyanate (Uniroyal 3316)	**
101912A (Adiprene CM)	RFL + Chem-lok 233	32	RFL + Chem-lok 233	41
101912A (Adiprene CM)	RFL + Chem-lok TS 2394-75	85	RFL + Chem-lok TS 2394-75	87

* RFL - Resorsinal Formaldehyde Latex
** Not run due to lack of greige Polyester cord

All coating adhesion peel samples were laminated using MEK solvent and cured under pressure in a simulated factory cure.

The RFL treatment on Nylon and Polyester was chosen for use with the Polypropylene Oxide 101910A gum. The RFL plus Chemlok TS 2394 system was chosen for use with the millable Urethane 101912A gum. Both these systems exceed the contract adhesion goal of 15 pounds per-inch.

2.3.2 Factory Running for Phase I, Task III Panel Fabrication

Eleven factory material compounding trials were made for the Phase I, Task III panel fabrication and for use in trial fabrications of prototype drums prior to making 10 drums for test and evaluation in Phase II, Task I. The details for these materials are shown in Figure 7.

Figure 7

Factory Material Running Details

Run #	Construction	Wt. oz/yd^2	Finished Width (in)	Thickness (in)	Coating Adhesion #/in Width @ 2"/min.	Yds. Run
D-646	Parel Liner Gum	39.68	54½	.045	N/A	60
D-647	Parel/Nylon Carcass	22.22	57	.027	36	60
D-648	Parel/Nylon Tread	51.33	57	.060	95	20
D-649	Adiprene Liner Gum	41.92	55	.048	N/A	50
D-650	Adiprene/ Nylon Carcass	27.44	55	.034	54	55
D-651	Adiprene/ Nylon Tread	59.49	55	.069	49	20
D-652	Polysulfide Liner Gum	63.72	53	.060	N/A	12
D-653	Parel/Polyester Carcass	27.70	57	.031	39	38
D-654	Parel/Polyester Tread	57.89	57	.066	82	22
D-655	Adiprene Polyester Carcass	31.05	54	.036	56	55
D-656	Adiprene/ Polyester Tread	54.52	54	.062	56	20

All tread, carcass and liner materials were calendered to the approximate thicknesses of their counterparts in the existing drum constructions with the exception of the carcass which was calendered on both sides with the minimum amount of gum possible and still allow adequate adhesion between plies.

2.3.3 Panel Fabrication for Phase I, Task III Testing

Three 24" x 24" panels of the 10 Phase I, Task III constructions were fabricated and cured. Two panels of each construction were used to supply samples for low temperature modulus determinations per ASTM D790, Method II, Procedure B. The test temperatures were 0^{o}F, -50^{o}F and -60^{o}F. Both fuel exposed and non-fuel exposed samples were supplied for testing. The fuel exposed samples were from panels having the liner side exposed to ASTM Fuel D for 4 days at 73^{o}F, air-dried at 73^{o}F for 2 days and oven-dried for 24 hours.

One 24" x 24" panel of each of the ten (10) Phase I, Task III constructions were shipped to the Contracting Officer's representative along with 8 ASTM slabs of each of the 3 candidate elastomer compounds. This completed requirements detailed under Contract Line Item 0001AA.

All panels were fabricated with the initial two cord plies crossed at a cord angle of 54^{o} to the center line followed by the last two cord plies in an identical manner. All ply-to-ply adhesion was achieved using MEK (Methyl Ethyl Ketone) as a freshener except the Polysulfide liner (D-652) which was bonded to carcass plies using Chemlok TS 2394 adhesive. The panels were cured with pressure. Panel details are shown in Figure 8.

Figure 8

Material Details for Phase I, Task III
Panel Fabrication

Construction Code	Construction Details*
A	Solid Polypropylene Oxide (compound #101961) using a 4 ply Nylon reinforcement. Tread 1 ply D-648, carcass 3 plies D-647, liner 1 ply D-646.
B	Solid Polypropylene Oxide (compound #101961) using a 4 ply noly-ester reinforcement. Tread 1 ply D-654, carcass 3 plies D-653, liner 1 ply D-646.
C	Polypropylene Oxide (compound #101961) with a Polysulfide liner (compound #101963) using a 4 ply Nylon reinforcement. Tread 1 ply D-648, carcass 3 plies D-647, liner 1 ply D-652.
D	Polypropylene Oxide (compound #101961) with a Polysulfide liner (compound #101963) using a 4 ply Polyester reinforcement. Tread 1 ply D-654, carcass 3 plies D-653, liner 1 ply D-652.
E	Solid Adiprene (compound #101962) using a 4 ply Nylon reinforcement. Tread 1 ply D-651, carcass 3 plies D-650, liner 1 ply D-649.
F	Solid Adiprene (compound #101962) using a 4 ply Polyester reinforcement. Tread 1 ply D-656, carcass 3 plies D-655, liner 1 ply D-649.
G	Adiprene (compound #101962) with a Polysulfide liner (compound #101963) using a 4 ply Nylon reinforcement. Tread 1 ply D-651, carcass 3 plies D-650, liner 1 ply D-652.
H	Adiprene (compound #101962) with a Polysulfide liner (compound #101963) using a 4 ply Polyester reinforcement. Tread 1 ply D-656, carcass 3 plies D-655, liner 1 ply D-652.
I	Polypropylene Oxide (compound #101961) with an Adiprene liner (compound #101962) using a 4 ply Nylon reinforcement. Tread 1 ply D-648, carcass 3 plies D-647, liner 1 ply D-649.
J	Polypropylene Oxide (compound #101961) with an Adiprene liner (compound #101962) using a 4 ply Polyester reinforcement. Tread 1 ply D-654, carcass 3 plies D-653, liner 1 ply D-649.

* Compound numbers are those assigned to production size D batches. Cross-reference is as follows:
  Polypropolene Oxide - 101961 - 101910A
  Adiprene CM - 101962 - 101912A
  Polysulfide ST - 101963 - 101913B

Samples of both unaged and fuel-aged composite constructions were cut from the sample panels and submitted for low temperature modulus determination to Cincinnati Testing Laboratories. Sufficient samples of each construction were supplied to facilitate testing the two most promising candidate materials for possible crystallinity by conditioning the samples for 240 min. instead of the 60 min. required in the initial testing.

2.3.4 Prototype Drum Fabrication

Two prototype drums were fabricated from construction A and construction F (see Figure 8 for details). These drums were fabricated to develop a learning curve for both fabrication and curing of these materials on factory equipment. The following characteristics were monitored:

1. Building tack - use of fresheners and adhesives

2. Cord alignment for proper mold fill out

3. Cure characteristics

It was determined that with both the Adiprene and the Parel materials, an improvement in building tack was needed. It was theorized that this could be accomplished through the use of tackifying resins in the freshening solution. Both of the subject drums were successfully built using these materials, however, the time required due to poor building tack was regarded excessive.

The cord alignment used to produce the current production drums with rayon cord was appropriate for drums fabricated with Nylon and Polyester cord reinforcements.

It had been noted in previous work that the Adiprene material was subject to reversion when cured in the presence of air. The trial drum made using construction "F" was purged with Nitrogen prior to cure; this procedure prevented liner reversion. No problems were encountered with the Parel construction "A" using standard production cure conditions.

After cure, both drums were outfitted with standard 500S hardware and air leak tested at 6 psi. No leakage was noted; girth measurements were taken at this point and are shown in Table XI. Both drums were then evacuated and filled with water, pressurized to 6 psi, and girth measurements recorded. The drums were then pressurized with water to 20 psi, the fitting bolts re-torqued and the girth measurements recorded. Pressures were then increased to 30 psi with water and girth measurements recorded at the time intervals reported in Table XI. No increase in girth was observed over the 2 hr. duration of this test. The pressure in both drums was sequentially increased to 35 psi and 40 psi with girth measurements

taken at each pressure. After the measurements were made at 40 psi, the pressure was relieved and the drums were dried and stored until final disposition. Table XI details the test sequence and the girth measurements recorded.

2.3.5 Analysis of Phase I, Task III Test Data

The Modulus of Elasticity test data for the 10 candidate composite constructions is presented in Table VI. The reported values represent an average of 3 test values. The $0^{o}F$ and $-30^{o}F$ testing was suspended due to the excellent performance of the candidates at the lower test temperatures. The data for the existing drum construction is included for comparison purposes.

All candidate drum constructions performed better than the existing drum constructions at the lower temperatures and were consistent with the original theoretical values predicted from early test data on the pure gum elastomers and cord reinforcement materials. Four of the drum constructions (A, B, C, D) showed better flexibility at $-60^{o}F$ than the existing construction showed at $0^{o}F$.

The worst candidate composite construction, the fuel aged E construction was 14 times better at $-60^{o}F$ than the existing construction.

2.3.6 Selection of Composite Constructions for Phase II, Task I Drum Fabrication

Discussions were held with the Contracting Officer's representative analyzing the test data. Agreement was reached on the two (2) constructions to be utilized in fabrication of the Phase II, Task I drums for testing under Mil-D-23119E, and eventual testing under actual arctic conditions. Five drums of each construction were to be produced. The two constructions selected were:

- A 4-ply Polyester cord reinforced construction using Polypropylene Oxide elastomer as the tread and carcass gum with a Polysulfide ST liner (Contract construction code letter "D". See Figure 8.)

- A 4-ply Polyester cord reinforced construction using Polypropylene Oxide elastomer as the tread and carcass gum with an Adiprene CM liner (Contract construction code letter "J". See Figure 8.)

The basis for the two (2) selected candidate constructions for Phase II, Task I drum fabrication is as follows:

a. Only slight differences in modulus were noted due to the type of reinforcement used, i.e. Nylon vs. Polyester cord. Polyester cord exhibited less elongation in the two trial drums fabricated.

b. The Polypropylene Oxide (Parel 58) compound 101910A performed consistently better as tread and carcass gum at low temperatures than the millable Urethane (Adiprene CM compound 101912A).

c. The all Polypropylene Oxide constructions showed better flexibility at -60°F than the standard production drum exhibited at 0°F. It is generally considered that the practical lower use limit for the standard drum is 0°F. Therefore, the Polypropylene Oxide construction should perform at -60°F as well as the standard construction performs at 0°F.

d. The Polypropylene Oxide compound exhibits relatively poor fuel resistance as is demonstrated in the volume swell and weight change data reported in Figure 2. Its performance was on the level of the Polychloroprene compound currently used as the tread gum. This performance is not sufficient to justify its further consideration as a liner (fuel barrier) material.

e. The volume swell data obtained for the millable Urethane compound 101912A and the Polysulfide compound 101913B suggest suitability as liner materials.

Additional low temperature modulus testing of constructions "D" and "J" were conducted at Cincinnati Testing Laboratories. Both constructions were tested at -60°F after being conditioned for 240 min. at -60°F. The original testing allowed only a 60 min. conditioning period. The additional time was added to detect any possible crystallization of the elastomer systems not detected during the initial testing. The test data indicates there is no significant difference in values obtained with the two conditioning time periods. The results are presented in Table VI.

2.4 Improved Hardware Design Phase I, Task IV

A low temperature performance test on the 2" adapter valve was performed using a Fluorosilicone gasket supplied to Uniroyal by Ft. Belvoir through the Contracting Officer's representative. The test was performed at -60°F. The adapter valve mechanism performed properly at this temperature, and successfully attached to the drum fitting via the cam lock mechanism. This operation was not possible with the standard Nitrile gasket normally provided with the valve.

It is recommended that the said gaskets, Part #MS27030-5 and MS27030-6, in the coupler valve assembly be replaced with Fluorosilicone gaskets for use below -30°F (-34°C) if valve and hose are to be removed and reinstalled at low temperatures.

All other hardware components appear to be functional at -60°F and were used on all Phase II drums shipped.

2.5 Phase II Improved Low Temperature Drum Fabrication and Testing

2.5.1 Drum Fabrication - Phase II, Task I

Production quantities of the tread, liner and carcass materials were for use in the fabrication of the 5 each "D" and 5 each "J" construction drums. The quantity of each material processed is noted below. (See Figure 7 for material details.)

D653 - Parel/Polyester Carcass Stock	(350 yds.)
D654 - Parel/Polyester Tread Stock	(120 yds.)
D649 - Adiprene Liner	(40 yds.)
D652 - Polysulfide Liner	(40 yds.)

The D652 Polysulfide liner material was run twice. The first running was lost due to scorch problems associated with its very short shelf life. The gum was remixed and calendered within one day of mixing to avoid this problem. The first calendering attempt was made 3 days after mixing.

2.5.1.1 Fabrication of "J" Construction Drums

A total of six (6) "J" construction drums were fabricated using Uniroyal's proprietary fabrication and curing technique. One drum SN#6 was scrapped due to severe ply delamination caused by a channel leak in the D649 liner. The remaining five (5) drums SN#3, #4, #5, #7 and #8 were successfully fabricated.

Several improvements in the building techniques were incorporated on these units as a result of the building of the two prototype units SN#1 and #2. These process changes are noted below:

- A 20% 1068 resin solution in MEK was used to freshen all carcass laps. This procedure improved the green tack to some extent; however, when left unattended for even short periods of time, i.e. 5 min., the laps would pull apart and have to be refreshened and put back in place.

- All tread laps were cemented with a 20% solution of 101961 (Parel) gum in MEK solvent. This, again, aided the building process but the same problem existed with the tread laps as was present in the carcass laps.

- A 20% solution of 101962 (Adiprene) gum in MEK solvent was used to cement all liner overlaps. This procedure worked very well with no problems encountered.

- A white identification ring was added on the ends of the drums to aid in identification during field testing.

2.5.1.2 Fabrication of "D" Construction Drums

A total of two (2) 500S "D" construction drums and three (3) 55 gal. "D" construction drums were fabricated. None of the drums fabricated resulted in a testable unit. The work effort to produce testable drums from the "D" construction are herein described.

The first "D" construction drum (SN 9) was unsuccessfully fabricated using the D652 Polysulfide liner stock. Severe problems in handling the D652 material occurred.

The material was extremely easy to tear making drum fabrication very difficult. The Chemlok TS 2394-75 cement, used in the D652 to D653 bonding area and the D652 liner laps, as well as the MEK solvent used to clean the adhesion surfaces aggravated the problem by making the D652 Polysulfide even more delicate to handle. The liner was repeatedly torn and repaired until a final decision was made to scrap the unit prior to cure.

A second attempt to fabricate a 500S "D" construction drum was made using an integral liner concept. A 35 yard factory calendering run was made to calender .025" of 101963 Polysulfide gum onto D653 Parel/Polyester carcass stock. This material was then used to fabricate a "D" construction drum (SN-10). This trial incorporated the use of a .060" thick Butyl strip liner which was built into the construction to maintain pressure during vulcanization. The Butyl liner would then be stripped out after cure leaving the 101963 liner molded in place. Problems developed during manufacturing due to the increased total construction thickness caused by the incorporation of the strip liner. The liners failed during vulcanization resulting in ply delamination in the unit. Pressure loss was extensive and the unit was scrapped.

Three additional building trials were conducted in an attempt to develop a viable manufacturing procedure for the "D" construction drums using the integral liner concept. The drum trials were made on 55 gal. sizes to conserve building materials and labor. The three drum constructions were as follows:

SN 11 - A Polysulfide integral liner drum using Adiprene D649 liner as tape stock to seal the lapped edges.

SN 12 - A Polysulfide integral liner using a .050" thick Chlorobutyl strip liner.

SN 13 - A Polysulfide integral liner using a .050" thick EPDM strip liner.

All three trials failed to produce acceptable units. The mode of failure was as follows:

SN 11 - The Adiprene tape slipped during cure allowing delamination to occur.

SN 12 - The unit failed to fill out properly due to the increased thickness from the strip liner. The liner also failed causing delamination.

SN 13 - The unit failed to fill out properly due to the increased construction thickness. The liner also failed causing delamination.

As a result of these failures, the program to produce a "D" construction drum was terminated.

2.6 Consideration, Fabrication and Testing of "D" Construction 2" I.D. Hose

Since the "D" construction did exhibit the best overall fuel and low temperature properties, the Contractor proposed that several lengths of hose be produced to evaluate the construction's potential as a fuel containment system. A small length (18") of prototype hose was produced to demonstrate the feasibility of a "D" construction in low temperature hose. This construction consisted of a .050 2-ply Polysulfide Liner 101963 gum, a carcass ply of D653 Parel/Polyester cord and a tread of D652 Parel/Polyester cord. The I.D. was proposed to be 2" and the reinforcement cross-ply angle was 54^{0}. The practical length which could be fabricated on existing Uniroyal equipment was 5 ft.

Sufficient material was available to enable the Contractor to fabricate and deliver 7 lengths of 2" I.D. hose 5 ft. long (less fittings) for evaluation of the "D" construction for potential use in arctic fuel hose.

The seven 5 ft. lengths of 2" I.D. hose were mandrel-built using Chemlok TS 2394-75 to bond Polysulfide liner to the D652 carcass stock. The bond of the D652 carcass stock to the D653 tread stock was achieved using a cement coat of 101961 gum dissolved at 20% in MEK solvent. The hoses were marked with a 1" wide white identification band and wrapped with 2 cross-wraps of Bally-Mills tape. The hoses were then autoclave-cured. The hoses were removed from the mandrel using hydrostatic pressure. The seven deliverable hoses were idenfified by serial number as SN 001, SN 002, SN 003, SN 005, SN 006, SN 007 and SN 008.

Peel adhesion tests at 2"/min. were run on samples mandrel-wrapped and cured with the SN 003 hose. Results are as follows:

Polysulfide liner to D652 carcass	9.5#/in.
D652 carcass to D653 tread	13.0#/in.

Each hose section was hydrostatically leak-tested for one (1) minute at 200 psi. At the end of the one (1) minute test, circumference and length measurements were taken and related to figures obtained at "0" psi (See Figure 9 below). After the measurements were taken, each hose was taken up to a 300 psi hydrostatic proof-pressure test at which point the pressure was immediately released.

Figure 9

Hose SN#	Circumference* (in) 0 psi	Circumference* (in) 200 psi	Length** (in) 0 psi	Length** (in) 200 psi
SN 001	7 7/16	7 7/8	48	49 1/16
SN 002	7 3/16	7 7/16	48	48 3/8
SN 003	7 3/16	7 9/16	48	48 11/16
SN 005	7 1/4	7 9/16	48	48 11/16
SN 006	7 3/16	7 7/16	48	49 1/4
SN 007	7 3/16	7 7/16	48	49 15/16
SN 008	7 1/4	7 7/16	48	49 1/2

* Measurements made within 6" of center of hose

** 4 ft. bench marked sections centered on hose length

Slight differences in the circumference growth and length between hoses was attributed to the difficulty in maintaining the exact 54^{o} angle while hand-laminating the construction.

2.7 Testing of "J" Construction Drums per Mil-D-23119E Phase II, Task II

First Article testing of the "J" construction was completed. The details of this testing are presented in Appendix I. Photographs of the testing are contained in Appendix II. The "J" construction passed all of the First Article tests with the exception of the following:

a. The minimum elongation for the outer rubber (tread) compound is 350%. The elongation of the 101961 Parel compound is 309% (see Table I, Appendix I). It would appear that this shortfall will have little affect on the drum especially in view of its excellent performance during the rolling tow test. The 309% figure does pass the 300% minimum specification value for the cord rubber (carcass) compound.

b. The hardness of the 101961 Parel gum is 5 points below both the cord rubber (carcass) and the outer rubber (tread) minimum value of 55 (see Table I, Appendix I). This lower hardness does not appear to be detrimental to drum performance.

c. The oil and fuel swell data for the 101961 Parel compound exceeds the requirements for the cord rubber. The fuel swell requirement for the outer cover compound (tread) was also exceeded. This could possibly result in eventual field service problems such as ply delamination and increased abrasion due to softening of the rubber by spilled fuels and oils.

d. Permeability data for the "J" construction is 1.055 fl. oz./ft^2/24 hrs. against a specification maximum of .1 fl. oz./ft^2/24 hrs. This higher diffusion may not be a significant factor if the drums are to be also used at low temperatures only; however, if the drums are to be also used at elevated temperatures, the higher diffusion could become a factor.

The low temperature collapsibility test on the "J" construction drum SN #4 is described in Appendix I. An additional cycle was run on the drum after the low temperature chamber was opened. Fuel at -60°F was pumped into the drum (see photographs in Appendix II) and its stiffness while being filled was noted. The drum appeared to be quite flexible indicating that its ability to be filled and emptied at low temperatures may exceed the -60°F Contract goal. After the drum was filled with 465 gal. of fuel, it was rolled back and forth to determine if a "flat spot" had developed on the bottom which would prevent the drum from being moved. This is a complaint which has been noted on the current drums at low temperatures. No flat spot was noted on the "J" construction (SN #4) drum.

Some testing of the "D" construction was conducted and is reported in Appendix I. This testing consisted of:

a. Innerliner testing per par. 3.4.1.

b. Permeability testing.

c. Non-volatile gum residue test.

d. Stove gum residue test.

e. Puncture resistance test.

Of the tests conducted on the "D" construction, two specification deficiencies were noted for the 101963 Polysulfide liner gum. Both the tensile and elongation figures for the Polysulfide gum are significantly lower than the required values. These lowered properties could possibly result in long term problems such as cracking and tearing of the liner after repeated flexing and creasing.

2.8 Drum Disposition

Seven (7) production drums were shipped to Ft. Belvoir, Virginia. Each drum was packed with Technical Manual TM-8110-2DI-14 & P. Attached to each manual was the "Notice" sheet shown in Table XII. This sheet defines the differences between these drums and standard construction drums. This sheet also defines each drum's testing history which may aid in planning future testing with the subject drums.

Seven (7) lengths of 2" I.D. x 5 ft. hose of the "D" construction were shipped to Ft. Belvoir for arctic evaluation.

3.0 Conclusions

The performance goals of this development effort were realized with the "J" construction drum.

The only significant trade-off in properties for the "J" construction was the fuel diffusion rate. At the use temperatures projected for these drums, this should not be a significant shortfall.

Although the "D" construction did prove to be impossible to fabricate on existing production equipment, the composite was fabricated into a hose which will be evaluated with the drums at low temperatures.

No major difficulties were experienced with the drum hardware at low temperatures. With the substitution of the 2 gaskets in the coupler valve, the hardware performed adequately at -60°F.

4.0 Recommendations

It is recommended that the "J" construction drums and the "D" construction hoses be evaluated under arctic conditions with various fuel types to determine suitability and use life under field conditions.

Further studies are recommended to improve the building tack of the Parel 101961 gum stock.

Further evaluation should be considered on the 101962 Adiprene liner material to improve fuel diffusion resistance.

Based on the Modulus of Elasticity test data and the actual low temperature collapsibility tests performed on the "J" construction, it would appear that the composite will perform at temperatures below the -60^{o}F test temperature. Studies to determine the lower use temperature limit should be conducted.

Table 1

Low Temperature Brittleness
Testing of Phase I Task I and Task II
Compounds Per ASTM D2137

Compound	Unaged				4 Days ASTM Fuel D @ 73°C			
	-30°F	-40°F	-50°F	-60°F	-30°F	-40°F	-50°F	-60°F
3130 Tread	OK	OK	CR	CR	3-OK	CR	CR	CR
3139 Carcass	CR	CR	CR	CR	CR	CR	CR	CR
3132 Liner	CR	CR	CR	CR	CR	CR	CR	CR
101910A Polypropylene Oxide	OK	OK	OK	OK	OK	OK	OK	OK
101910B Polypropylene Oxide Blend	OK	OK	OK	OK	OK	OK	OK	OK
191911A Millathane 76	CR	NT	NT	NT	CR	NT	NT	NT
101911B Millathane 100	OK	CR	NT	NT	OK	OK	CR	CR
191912D Adiprene CM	OK	OK	OK	OK	OK	OK	OK	OK
101913C Polysulfide FA	OK	CR	CR	CR	OK	CR	CR	CR
101913E Polysulfide ST	OK	OK	OK	OK	OK	OK	CR	CR

OK - None of the 5 samples cracked

CR - 5 of the 5 samples cracked

NT - Not Tested

Table II

Modulus of Elasticity $E_B \times 10^5$
Unaged

	0^oF	-30^oF	-40^oF	-50^oF	-60^oF	Factor to 0^oF
Existing Liner Gum (3132)	.094	5.32	7.30	9.07	9.59	102
Existing Carcass Gum (3139)	.0295	1.45	4.14	7.26	8.72	295
Existing Tread Gum (3130)	.0512	.0373	.086	.688	5.54	108
101910A Polypropylene Oxide	.0456	.0307	.0317	.0332	.047	1.03
101910B Polypropylene Oxide Blend	.0567	.0451	.199	1.66	2.52	44
101911A Millathane 76	.101	5.27	8.38	9.49	10.21	101
101911B Millathane 100	.0493	1.86	5.52	7.86	8.62	175
101912A Adiprene CM	.0209	.0227	.0337	.0508	.132	6.32
101913A Polysulfide FA	.0722	.0833	.116	.236	2.90	40
101913B Polysulfide ST	.0436	.0352	.0426	.0810	.119	2.73

$$\text{Factor to } 0^oF = \frac{\text{Value @ } -60^oF}{\text{Value @ } 0^oF}$$

Table III

Modulus of Elasticity ($E_B \times 10^5$)
ASTM Fuel D Aged 4 Days @ 73°F

	0°F	-30°F	-40°F	-50°F	-60°F	Factor to 0°F
Existing Liner Gum (3132)	.0486	2.68	5.37	7.33	8.64	178
Existing Carcass Gum (3139)	.0198	.904	2.65	4.69	6.03	304
Existing Tread Gum (3130)	.0331	.0477	.098	.955	4.15	125
101910A Polypropylene Oxide	.0378	.0229	.0309	.0308	.0456	1.21
101910B Polypropylene Oxide Blend	.0309	.0265	.0836	.983	2.01	65
101911A Millathane 76	.0856	3.8	7.75	9.53	9.74	114
101911B Millathane 100	.0366	1.31	4.16	7.19	8.36	229
101912A Adiprene CM	.0297	.0306	.0882	.24	.902	30.4
101913A Polysulfide FA	.0603	.0723	.103	.226	2.12	35.2
101913B Polysulfide ST	.0346	.0355	.0446	.0812	.12	3.47

$$\text{Factor to } 0^{\circ}F = \frac{\text{Value @ } -60^{\circ}F}{\text{Value @ } 0^{\circ}F}$$

Table IV

Flexural Strength PSI
Unaged

Sample Description	0°F	-30°F	-40°F	-50°F	-60°F	Factor to 0°F
			Test Temperature			
Existing Liner Gum (3132)	312	6580	10750	13160	12930	41.4
Existing Carcass Gum (3139)	122	1470	5230	10190	8540	70
Existing Tread Gum (3130)	170	125	254	673	4740	27.9
101910A Polypropylene Oxide	233	134	108	118	162	.7
101910B Polypropylene Oxide Blend	248	183	381	1660	2960	11.9
101911A Millathane 76	342	8460	12650	11770	13260	38.8
101911B Millathane 100	211	2550	9010	14280	16280	77.2
101912A Adiprene CM	95	68	123	170	319	3.4
Polysulfide FA	305	297	369	804	2690	8.8
101913B Polysulfide ST	193	151	168	268	431	2.2

$$\text{Factor to } 0^{\circ}\text{F} = \frac{\text{Value @ } -60^{\circ}\text{F}}{\text{Value @ } 0^{\circ}\text{F}}$$

Table V

Flexural Strength PSI
ASTM Fuel D Aged 4 Days @ 73°F

Sample Description	0°F	-30°F	-40°F	-50°F	-60°F	Factor to 0°F
			Test Temperature			
Existing Liner Gum (3132)	208	2920	5420	7700	9710	46.7
Existing Carcass Gum (3139)	83	813	2570	5460	6930	83.5
Existing Tread Gum (3130)	118	165	270	815	2970	25.2
101910A Polypropylene Oxide	195	160	104	139	175	.9
101910B Polypropylene Oxide Blend	151	149	244	1090	2310	15.2
101911A Millathane 76	294	5690	12940	13110	12190	41.5
101911B Millathane 100	137	1390	5720	11210	16400	119.7
101912A Adiprene CM	126	110	259	483	1360	10.8
101913A Polysulfide FA	258	277	383	745	1920	7.44
101913B Polysulfide ST	198	178	197	298	483	2.4

$$\text{Factor to } 0^{o}\text{F} = \frac{\text{Value @ } -60^{o}\text{F}}{\text{Value @ } 0^{o}\text{F}}$$

TABLE VI

EXISTING AND
CANDIDATE COMPOSITE CONSTRUCTIONS
MODULUS OF ELASTICITY

$E_B \times 10^3$

Construction I.D.*	UNAGED					FUEL AGED				
	0^oF	-30^oF	-40^oF	-50^oF	-60^oF	0^oF	-30^oF	-40^oF	-50^oF	-60^oF
Existing Construction	5.21	234	350	423	635	8.81	186	345	417	426
A P/N/P			4.14	3.47	4.91			3.66	3.05	3.55
B P/P/P			4.73	4.70	4.04			3.99	3.56	3.44
C P/N/S			4.57	6.08	6.51			4.50	6.30	7.89
D*** P/P/S			6.08	4.94	6.24 6.43**			5.16	5.53	5.77 6.20**
E A/N/A			4.43	7.35	19.7			5.61	15.7	46.1
F A/P/A			3.87	6.60	19.3			5.06	10.4	37.3
G A/N/S			6.18	10.7	25.55			5.36	9.5	22.45
H A/P/S			6.70	11.9	25.1			6.87	12.0	27.75
I P/N/A			5.50	8.37	11.5			5.43	8.46	13.8
J*** P/P/A			4.61	7.20	11.95 8.46**			6.69	8.60	14.3 10.65**

* Construction code: (see Figure 5)

(Tread & Carcass)	(Reinforcement)	(Liner)
P = Parel 58	N = Nylon	P = Parel 58
A = Adiprene CM	P = Polyester	A = Adiprene CM
		S = Polysulfide ST

** Samples conditioned for 240 min. at test temperature

*** Constructions for drum fabrication

TABLE VII

Existing and Candidate Reinforcement Cord Data

Property	Existing Reinforcement Rayon	Candidate Reinforcement Nylon	Polyester	Kevlar I	Kevlar II
Denier	1650	840	1000	1500	1500
Plies	2	2	2	1	2
Ends/in.	21.05	22.6	22.4	23	12
Cord Diameter (in.)	.028	.021	.021	.008	.012
Breaking Strength (lbs.)	31.6	32.3	30.8	61.5	77
Breaking Elongation	19.14	19.7	19.6	3.6	4.1
Tensile Modulus					
$70^{o}F$	265,000	435,000	410,000	$10.1x10^{6}$	$6.9x10^{6}$
$-30^{o}F$	285,000	425,000	380,000	$11.2x10^{6}$	$10.6x10^{6}$
$-40^{o}F$	300,000	505,000	490,000	$10.8x10^{6}$	$6.2x10^{6}$
$-50^{o}F$	310,000	500,000	510,000	$11.1x10^{6}$	$6.8x10^{6}$
$-60^{o}F$	320,000	415,000	520,000	$10.8x10^{6}$	$6.7x10^{6}$

CINCINNATI TESTING LABORATORIES, INC.

REPORT NO. TL-4841

TABLE VIII

APPARENT MODULUS

CUSTOMER:	Uniroyal, Inc.	DATE:	January 5, 1983
MATERIAL:	3/8" Nominal Diameter Steel Cable (.025" dia. steel braided)		
PRECONDITIONING:	None (As Received)	SUPPORT RADIUS:	1/4"
TEST CONDITION:	See Below	NOSE RADIUS:	1/4"
TEST SPAN(L):	6.0	TEST SPEED:	0.16 in./min.
L/d RATIO:	16/1	SPECIMEN LENGTH:	10 inches

$$\text{Apparent Modulus}(E) = \frac{4L^3M}{3\pi d^4}$$

L = Test Span in inches

M = Initial slope of load-deflection curve in lbs. per in

d = nominal specimen diameter in inches (.375")

Test (No.)	E (PSI x 10^4)	M (lbs./in.)	Test Condition
1	6.62	14.29	74°F
2	7.05	15.20	60 min. @ -60°F tested @ -60°F

NOTE: Since this is an apparent modulus, these values should be used for comparison only.

Test Technician: C. Myers

Approved: D. Brown

TABLE IX

CANDIDATE TREAD AND LINER COMPOUND FORMULATIONS

101910 Series Polypropylene Oxide)

	A	B
Parel 58	100	50
HAF Black	40	40
Zinc Oxide	5	5
Stearic Acid	1.0	1.0
NBC	1.0	0.5
TMTM	1.5	0.75
MBT	1.5	0.75
Sulfur	1.25	.60
Neoprene W	-	50
Maglite D	-	2.0
END 75	-	0.35
101911 Series (Millathane)		
Millathane 76	100	-
Millathane 100	-	100
HAF Black	30	30
MBTS	4.0	4.0
MBT	2.0	2.0
Curathane	1.0	1.0
Cadmium Stearate	0.5	0.5
Sulfur	1.5	1.5
Activator 2013P	9	9
Plasticizer TP90B	2	2
101912 Series (Adiprene CM)		
Adiprene CM	100	
HAF Black	30	
Plasticizer SC	15	
Sulfur	0.75	
MBTS	4.0	
MBT	1.0	
Caytur 4	0.35	
Cadmium Stearate	0.5	
101913 Series (Polysulfide)		
Polysulfide FA	100	-
Zinc Oxide	10	-
SFR Black	60	60
Stearic Acid	0.25	1.0
MBTS	0.4	-
DPG	.1	-
Polysulfide ST	-	100
Calcium Hydroxide	-	1.0
Zinc Peroxide	-	5.0
Plasticizer TP95	-	4.0
101914 Series (Fluorosilicone)		
Silastic LS 422	100	
DiCup 40C	1.9	
Cab-O-Sil MS-7	20	

TABLE X

Physical Property Values of Phase I Task II Compounds

Candidate Liner and Tread Compounds

Compound*/Cure	Tensile (psi)	Elongation (%)	Shore A Hardness
101910A Polypropylene Oxide (20' @ 310°F)	1492	309	58
101910B Polypropylene Oxide Blend (35' @ 310°F)	1945	386	53
101911A Millathane 76 (30' @ 290°F)	3131	656	65
101911B Millathane 100 (30' @ 290°F)	2994	654	64
101912A Adiprene CM (60' @ 290°F)	2233	567	56
101913A Polysulfide FA (40' @ 300°F)	1208	249	66
101913B Polysulfide ST (30' @ 310°F)	1003	231	66
101914A Fluorosilicone (10' @ 300°F)	1149	109	73

* Physical properties run on press cured ASTM slabs at the times and temperatures indicated.

TABLE XI

Prototype Drum Pressurization and Girth Measurements

SN1 - "A" Construction Parel/Nylon		SN2 - "F" Construction Adiprene/Polyester	
Pressure/Type	Girth	Pressure/Type	Girth
6 psi/air	14' 3-3/8"	6 psi/air	14' 3-1/8"
6 psi/air	14' 5-7/8"	6 psi/H_2O	14' 3-3/4"
20 psi/H_2O	14" 11-1/2"	20 psi/H_2O	14' 8"
30 psi/H_2O @ 0 min.	15' 6-1/8"	30 psi/H_2O @ 0 min.	14' 11-1/4"
30 psi/H_2O @ 15 min.	15' 6-1/8"	30 psi/H_2O @ 15 min.	14' 11-1/4"
30 psi/H_2O @ 30 min.	15' 6-1/8"	30 psi/H_2O @ 30 min.	14' 11-1/4"
30 psi/H_2O @ 45 min.	15' 6-1/8"	30 psi/H_2O @ 45 min.	14' 11-1/4"
30 psi/H_2O @ 2 hrs.	15' 6-1/8"	30 psi/H_2O @ 2 hrs.	14' 11-1/4"
35 psi/H_2O	15' 7-1/8"	35 psi/H_2O	15' 1-11/16"
40 psi/H_2O	15' 8-1/2"	40 psi/H_2O	15' 3-3/8"

Table XII

- N O T I C E -

This Drum is suitable for use at -60°F. It was developed and fabricated under Contract #DAAK70-82-C-0115.

Operation and maintenance of Drum is outlined in the manual attached with the following exceptions:

1. Drum is serviceable to -60°F (-51°C).

2. Gaskets - Part #MS27030-5 and MS27030-6 in coupler valve assembly must be replaced with silicone gaskets for use below -30°F (-34°C) if valve and hose are to be removed and reinstalled at low temperatures. Gaskets may be obtained through MERADCOM (Tel. 703/664-5781 - Mr. C. Browne.)

3. The repair procedures outlined in the manual are not applicable to these Drums. Repair of these Drums requires special materials and cement. If repair is required, contact Uniroyal (Tel. 219/256-8670 - Mr. D. V. Perkins) for repair materials, cements and procedures. Clamps and plugs may be used on these Drums for emergency repairs.

DRUM HISTORY

	SN #1	SN #2	SN #3	SN #4	SN #5	SN #7	SN #8
Construction Type	P/N/P	A/P/A	P/P/A	P/P/A	P/P/A	P/P/A	P/P/A
Contract Construcion Code	A	F	J	J	J	J	J
Uniroyal Construction	S296X	S297X	S294X	S294X	S294X	S294X	S294X
Tests Per Mil-D-23119E							
6 PSI Leak	X	X	X	X	X	X	X
30 PSI Proof	X	X	X	X	X	X	X
Expansion Test	X	X					X
Fuel S'orage					X		
Air Drop					X		
Weight							X
Ambient Collapsibility							X
Rolling Tow							X
Ultimate Pressure				X			
Low Temp. Collapsibility				X			

APPENDIX I

CONTRACT DAAK70-82-C-0115
FIRST ARTICLE TESTING

FACTUAL DATA

1.0 Pre-Production Testing

1.1 Examination

Reference paragraph 4.5.3 of MIL-D-23119E.

1.1.1 The three drums, S/N's 4, 5 and 8, were examined in accordance with paragraph 4.6.1 of MIL-D-23119E and UNIROYAL Quality Assurance Procedure USR No. 0562.

1.2 Hardware Inspection

Reference paragraph 4.6.1 characteristic 104, 105, of MIL-D-23119.

1.2.1 The drum hardware was not inspected to the applicable part drawing. Standard 500S hardware purchased for military use was utilized to fit all contract drums.

1.3 Drum Material Samples

Reference paragraph 4.6.2.1 of MIL-D-23119E.

1.3.1 Permeability Test

1.3.1.1 The Permeability Test was conducted in accordance with ASTM D 814 on a cross section piece of the drum wall construction. This test was performed using an aluminum cup with a suitable clamping device and the test liquid was Fuel B of ASTM D 471. The permeability rate of fluid through the drum was .0139 fl. oz./sq. ft./24 hrs. for the D construction and 1.055 fl. oz./sq. ft./

1.3.1.1 (cont'd.) 24 hrs. for the "J" construction. The "D" construction meets the requirements of paragraph 3.6.1 of MIL-D-23119E. The "J" construction does not pass the specification requirement of .10 fl. oz./sq. ft./24 hrs.

1.3.2 Nonvolatile Gum Residue Test

1.3.2.1 A five gram sample of the inner liner drum wall was diced up in approximately 0.062 inch squares and placed in a flask containing 250 ml. of test fluid for 48 hours at 77^{O}F. At the completion of the 48 hours, the test fluid was decanted off and tested for existing gum in accordance with the air-jet solvent wash method of ASTM D 381. A blank was run on the test fluid at the same time and by the same method. The existent gum of the blank fuel was subtracted from the existent gum obtained from the test fluid used with the drum sample. The amount of nonvolatile gum residue extracted from the 101963-Polysulfide inner liner material of the drum wall was .048 mg./100 ml, and .133 mg./100 ml for the 101962 Adiprene. This meets the requirements of paragraph 3.6.2 of MIL-D-23119E.

1.3.3 Stove Gum Residue Test

1.3.3.1 The beakers containing the nonvolatile material were placed in an appropriate bath and the temperature was maintained constantly at 572^{O}F for a period of 30 minutes. After cooling in a closed container, the beakers were weighed and the weight was .048 mg./100 ml. for the 101963 Polysulfide, and .005 mg./100 ml for the 101962 Adiprene. This meets the requirements of paragraph 3.6.3 of MIL-D-23119E.

1.3.4 Puncture Resistance Test

1.3.4.1 The drum wall was puncture tested in accordance with paragraph 4.6.17 of MIL-T-6396. The drum specimen was fastened to a specimen holder and a piercing instrument was forced against the drum wall at approximately the center of the area. The rate of travel did not exceed 20 inches per minute. The force required to puncture the "D" construction drum wall specimen was 288 pounds. The force required for the "J" construction was 292 pounds. These values meet the requirements of paragraph 3.6.5 of MIL-D-23119E.

1.4 Materials

Reference paragraph 3.4 of MIL-D-23119E.

1.4.1 Representative samples were taken on the materials used in manufacturing the compounds that are used to fabricate low temperature fuel drums. The compounds were tested in accordance with the applicable ASTM D2000 specifications. The test data is listed in Tables I and II.

2.0 Tests

2.1 Expansion Test

Reference paragraph 4.6.2.2.1 of MIL-D-23119E.

2.1.1 Drum Serial Number 8 was filled with water until a pressure of 30 PSIG was obtained. The length and diameter was then measured within 15 minutes. The length was 59¼ inches long and the diameter was 57 3/4 inches. The drum was left standing

2.1.1 (cont'd)	for a period of 7 hours. At the end of 7 hours, the drum was measured. The length was 59 3/4 inches long and the diameter was 58¼ inches. The difference in the length was 1/2 inch and the difference in the diameter was 1/2 inch. The test was successful in accordance with paragraph 3.6.5 of MIL-D-23119E.

2.2 Weight Test

Reference paragraph 4.6.2.2.2 of MIL-D-23119E.

2.2.1 The empty drum with hardware was weighed and did not exceed the weight requirements of paragraph 3.6.6 of MIL-D-23119D. The weight was as follows: S/N 8 = 254 pounds.

2.3 Ultimate Pressure Test

Reference paragraph 4.6.2.2.3 of MIL-D-23119E.

2.3.1 Drum Serial Number 4 was subjected to a hydrostatic pressure of 45 PSIG and allowed to stand for 30 minutes. At the end of five minutes, the pressure was readjusted to 45 PSIG. At the end of 30 minutes, the drum was examined for compliance of paragraph 3.7.1 of MIL-D-23119E. There was no visual evidence of leakage, external or internal component layer separation, delamination, or blistering.

2.4 Proof Pressure Test

Reference paragraph 4.6.2.2.4 of MIL-D-23119E.

2.4.1 Each drum (S/N's 1, 2, 3, 4, 5, 7 and 8) was subjected to a hydrostatic pressure of 30 PSIG and allowed to stand for a period of 30 minutes. At the end of 5 minutes, the pressure was

2.4.1 (cont'd)	readjusted to 30 PSIG. At the end of 30 minutes, each drum was visually inspected and there was no evidence of leakage.

2.5 <u>Fuel Storage Test</u>

Reference paragraph 4.6.2.2.5.1 of MIL-D-23119E.

2.5.1 Drum Serial Number 5 was filled with 450 gallons of Regular Non-Leaded gasoline (Reference TWX R221910Z - Oct. 80 REC. CDR TSARCOM St. Louis) and left standing for 72 hours. At the end of each 24 hour period, the drum was rotated 180° and visually examined for leakage. At the end of the 72 hour period, the drum was visually examined and there was no sign of leakage. The hardware was then removed and the drum was examined internally. This examination revealed there was no change from original examination. The test was acceptable in accordance with paragraph 3.7.3 of MIL-D-23119E.

2.6 <u>Airdrop Test</u>

Reference paragraph 4.6.2.2.5.2 of MIL-D-23119E.

2.6.1 After the completion of the Fuel Storage Test, the S/N 5 drum was reassembled and refilled with 450 gallons of water. The drum was then lifted by the two anchor shackles on the fill end to a height of 12' 6" to the bottom of the drum. The drum was then released and fell on unprepared ground. This drop test was performed three times. The drum was visually examined and there was no evidence of leakage. The drum was then emptied and the hardware was removed and examined internally and externally. There was no evidence of broken hardware or change

2.6.1 (cont'd)	from the examination after fuel storage. The drum was emptied within three hours and examined in accordance with paragraph 3.7.4 of MIL-D-23119E.

2.7 <u>Rolling Tow Test</u>

Reference paragraph 4.6.2.2.6 of MIL-D-23119E.

2.7.1 The drum Serial Number 8 was filled with 345 gallons of water and pressurized to 5 PSIG with air. Water was used instead of fuel to facilitate towing on a public paved roadway. The 345 gal. represents the weight of 450 gal. of fuel. This change in test was discussed with and agreed to by the contracting officer's representative. The tow bar was attached to the lugs and the drum was towed for a distance of 10 miles at an average speed of 5 to 10 miles per hour. At the end of 10 miles, the drum was visually examined per paragraph 3.7.5 of MIL-D-23119E and no evidence of leakage was found.

2.8 <u>Low Temperature Collapsibility Test</u>

Reference paragraph 4.6.2.2.7 of MIL-D-23119E with the exception that the test temperature was $-60^{O}F \pm 2^{O}F$.

2.8.1 The drum Serial Number 4 and gasoline was placed into the test chamber and the temperature was lowered to $-60^{O}F$. The drum was then filled with 465 gallons of the cooled gasoline and left stand for a period of 24 hours. The drum was then emptied of 457.8 gallons of gasoline when subjected to a minimum vacuum of 12 inches of mercury. This test was conducted in a cold chamber with the temperature at $-60^{O}F$ and the drum in

2.8.1 (cont'd) a horizontal position. The drum was then examined in accordance with paragraph 3.7.6 of MIL-D-23119E and showed no evidence of leakage, blistering, delamination, splits or cracks, chipping of sloughing.

2.9 Ambient Temperature Collapsibility Test (In Progress)

Reference paragraph 4.6.2.2.8 of MIL-D-23119E.

2.9.1 Drum Serial Number 8 was filled with 465 gallons of gasoline and emptied of not less than 435 gallons a total of 75 cycles. The 75 cycles were completed by metering in 465 gallons of gasoline and then, reversing the pump, the gasoline was metered out. At the end of each emptying, a minimum vacuum of 12 inches Hg. was pulled. At the end of 75 cycles, the drum was drained, the drum hardware was removed and the inside of the drum was visually inspected. There was no evidence of damage to the liner, internal blistering or delamination.

2.10 Leakage Test

Reference paragraph 4.6.2.2.10.

2.10.1 Each drum (S/N's 1, 2, 3, 4, 5, 7, and 8) was inflated with 6 PSIG of air. After the drums were inflated, a sudsing solution was sprayed over the entire drum surface. The drum was then visually examined for any evidence of leaking. This was determined by looking for any sign of fizzing or bubbling of the sudsing solution. There was no leakage observed when examined in accordance with paragraph 3.7.9 of MIL-D-23119E.

2.11 Sleeve and Wire Rope Assembly Test

Reference paragraph 4.6.2.2.11. This test was not conducted as agreed to by the Contracting Officer's representative.

Table I

Contract DAAK70-82-C-0115

Outer Cover Compound and Cord Rubber Compound

Tested in Accordance With
Par. 3.4.2 and Par. 3.4.3 of MIL-D-23119E
(ASTM D2000 2BC615, A14, EF21, C12)
(ASTM D2000 5BG615, A14, EF21)

	Test	Outer Cover Requirement	Cord Rubber Requirement	Parel 101961 Results	Adiprene 101962 Results
2BC615	Tensile Strength ASTM D412 Die C	1500 psi (min)	1500 psi (min)	1803	2843
	Elongation ASTM D412 Die C	350% (min)	300% (min)	309	410
	Shore A Hardness ASTM D2240	60 ± 5	60 ± 5	50	55
	Oil Immersion ASTM D471 #3 Oil 70 hrs. @ 100°C Volume Swell	+120% (max)	+40% (max)	+95	+15
	Compression Set ASTM D395 Solid Max % 22 hrs. @ 100°C	80% (max)	50% (max	+28	+33
A14	Heat Resistance ASTM D573 70 hrs @ 100°C				
	Change in Hardness	+15% (max)	+15% (max)	+11	0
	Change in Tensile	-15% (max)	-20% (max)	-15	-7
	Change in Elongation	-40% (max)	-40% (max)	-34	-8
EF21	Volume Swell Ref Fuel B ASTM D471, 70 hrs. @ 23°C	+65% (max)	+65% (max)	+70	+17
C12	Resistance to Ozone ASTM D1171, Method A 38°C	100	-	100	100

Table II

Contract DAAK70-82-C-0115
Innerliner Compound

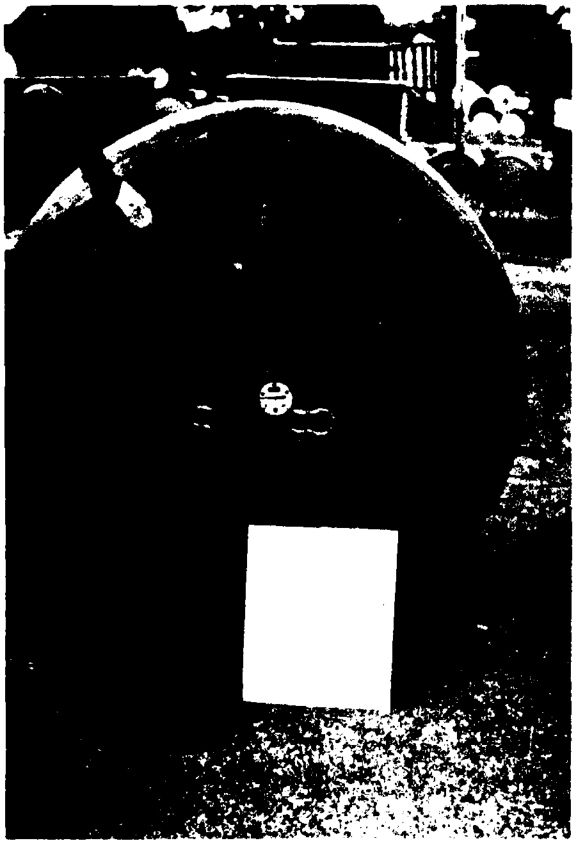
Tested in Accordance with
Par. 3.4.1. of MIL-D-23119E
(ASTM D2000 Composition 5BG615, A14, EF21
Requirement for EF21 Shall Be 50% Max.)

	Test	Requirement	Adiprene 101962 Results	Polysulfide 101963 Results
5BG615	Tensile Strength ASTM D412 Die C	1500 psi (min)	2843	996
	Elongation ASTM D412 Die C	300% (min)	410	198
	Shore A Hardness ASTM D2240	60 ± 5	55	56
	Volume Swell ASTM #3 Oil 70 hrs. @ 100°C per ASTM D471	+40% (max)	+15	+9
	Compression Set ASTM D395 Solid, Percent, 22 hrs. @ 100°C	50% (max)	+33	+31
EF21	Volume Swell Ref Fuel B ASTM D471 70 hrs. @ 23°C	50% (max)	+17	+6
A14	Heat Resistance, ASTM D573 70 hrs @ 100°C			
	Change in Hardness	+15 (max)	0	+7
	Change in Tensile	-20% (max)	-7	+13
	Change in Elongation	-40% (max)	-8	+1

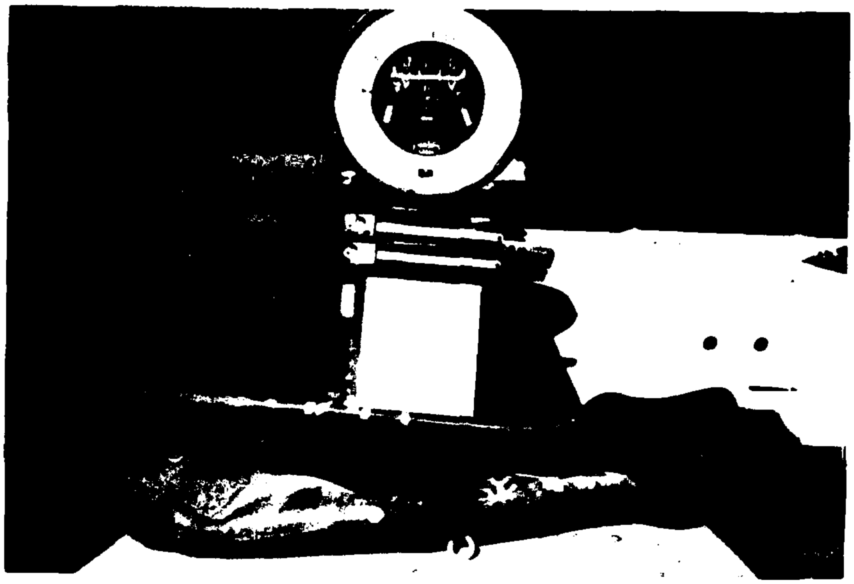
APPENDIX II

CONTRACT DAAK70-82-C-0115

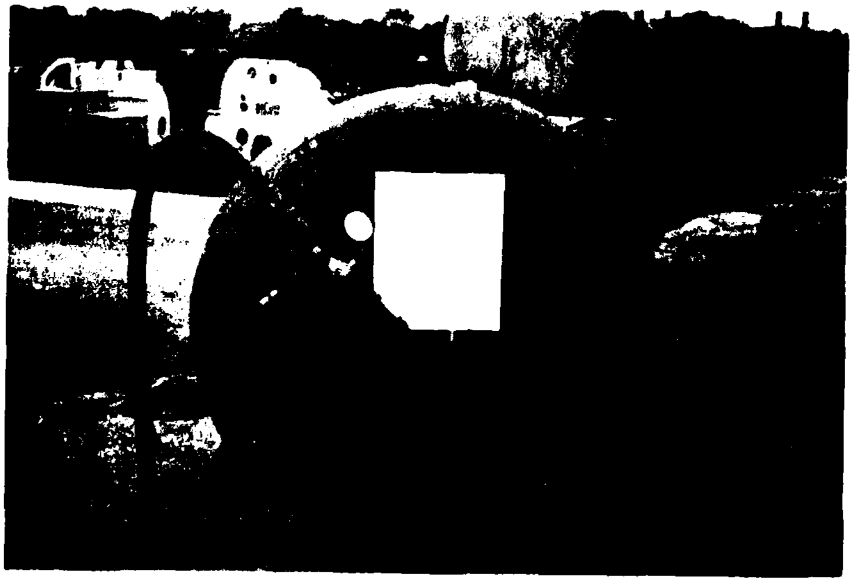
S295X CONSTRUCTION PHOTOGRAPHS OF 1ST ARTICLE TESTING PER. MIL-D-23119-E



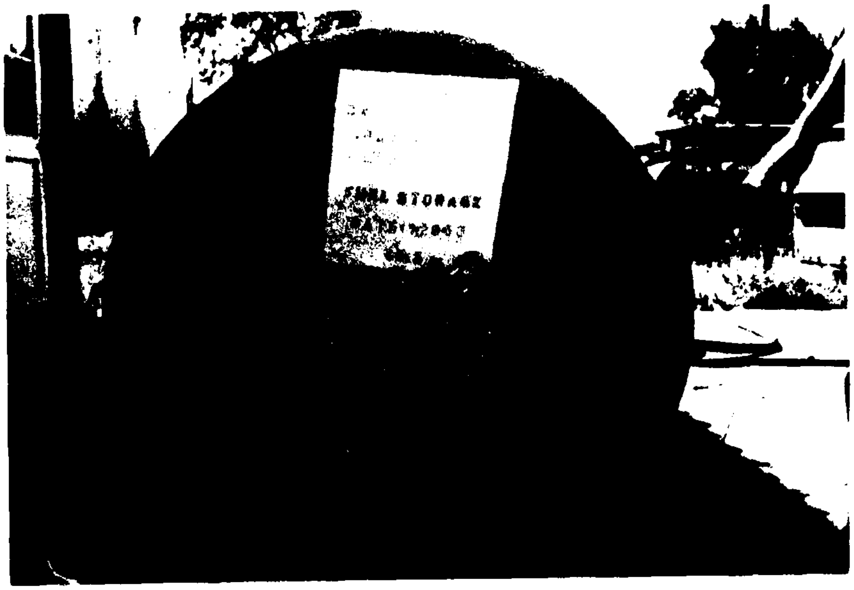
SN 8 EXPANSION TEST



SN 8 WEIGHT CHECK

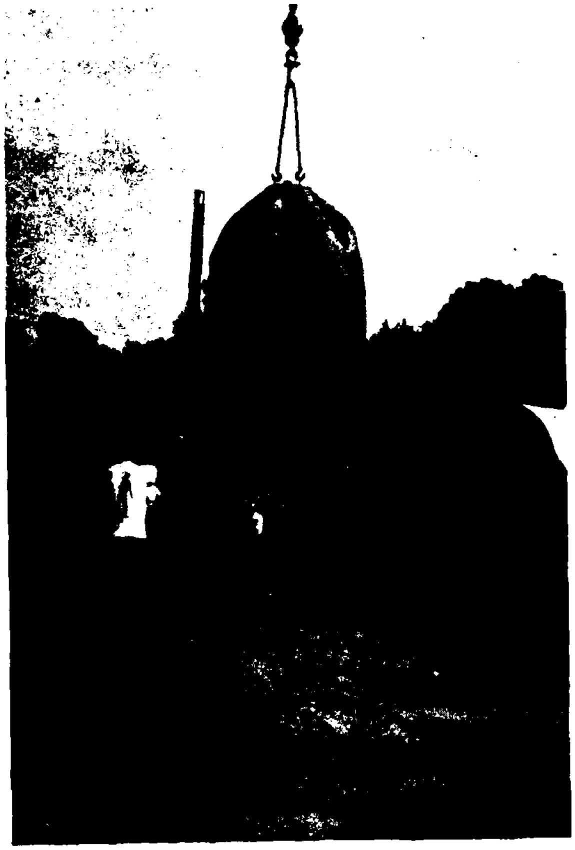


SN 4 ULTIMATE PRESSURE

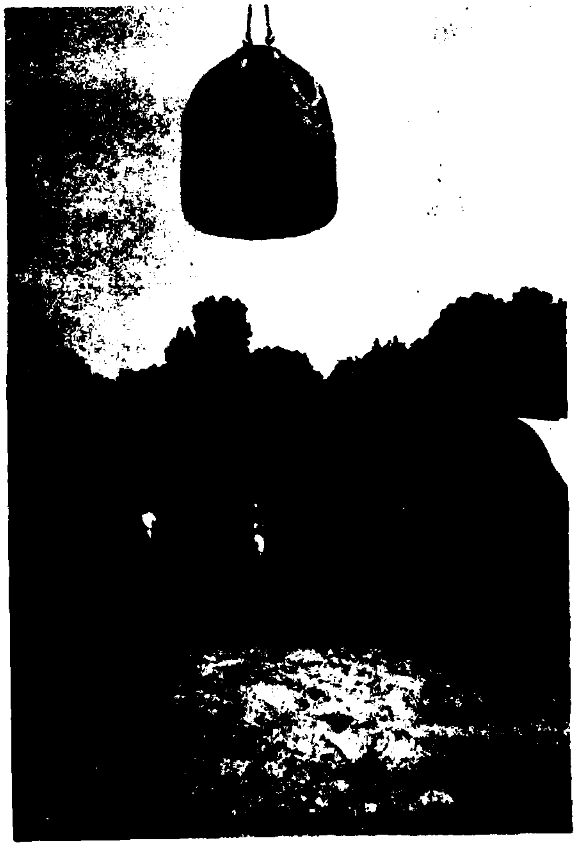


SN5 FUELSTORAGE

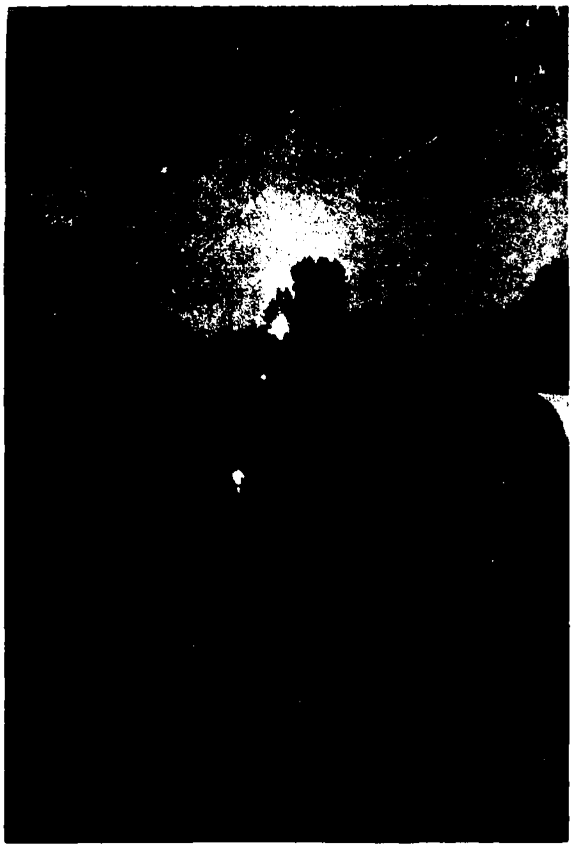
SN 5 AIR DROP
SET UP PRIOR TO 1ST DROP



SN 5 AIR DROP
RAISING DRUM
TO 12.5 FT. PRIOR
TO 1ST DROP

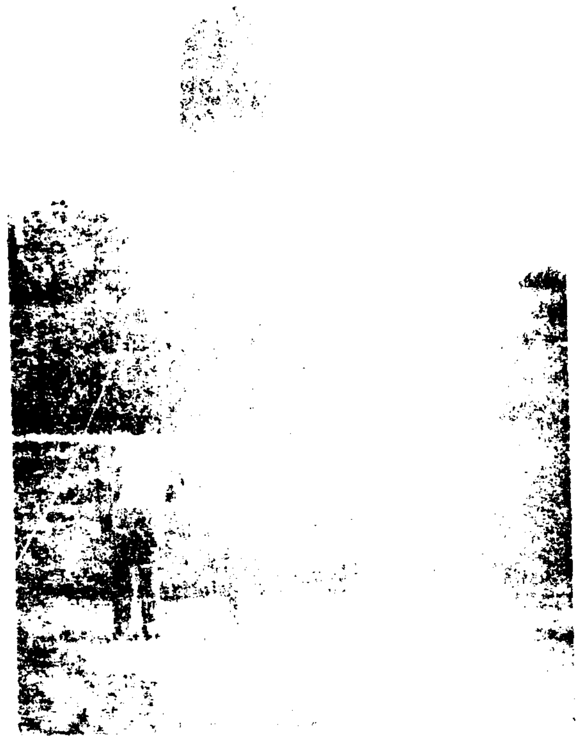


SN 5 AIR DROP
DRUM AT 12.5 FT.
PRIOR TO DROP

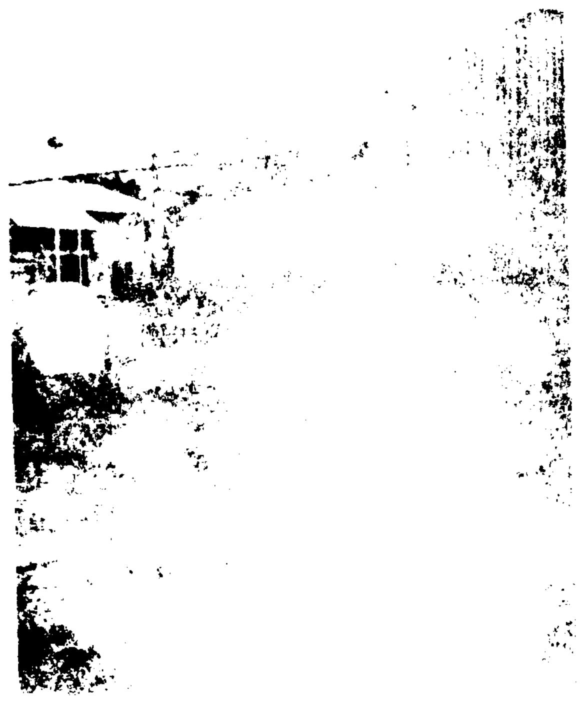


SN 5 AIR DROP
DRUM JUST
PRIOR TO 1ST
IMPACT

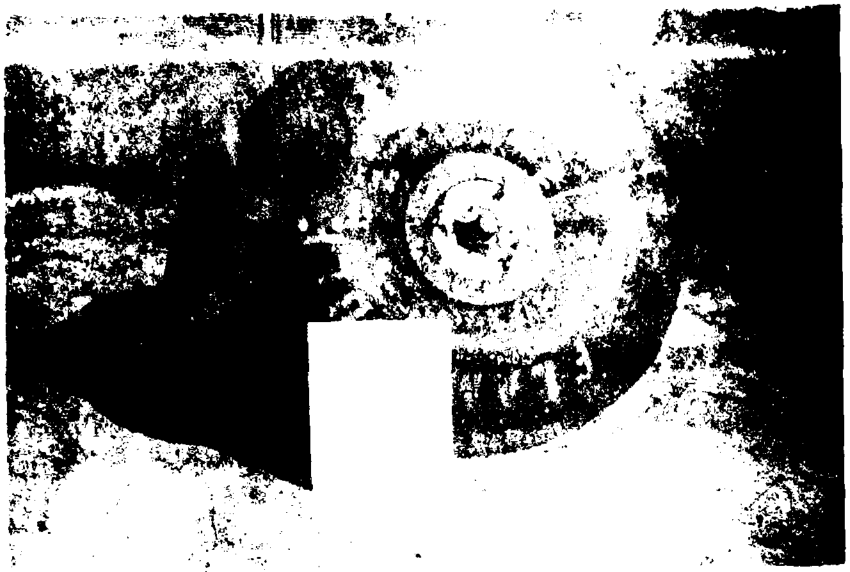
SN 5 AIR DROP
DRUM AFTER 1ST IMPACT



SN 5 AIR DROP
DRUM AT 12.5 FT.
PRIOR TO 3RD
DROP



SN 5 AIR DROP
DRUM JUST AFTER
3RD DROP

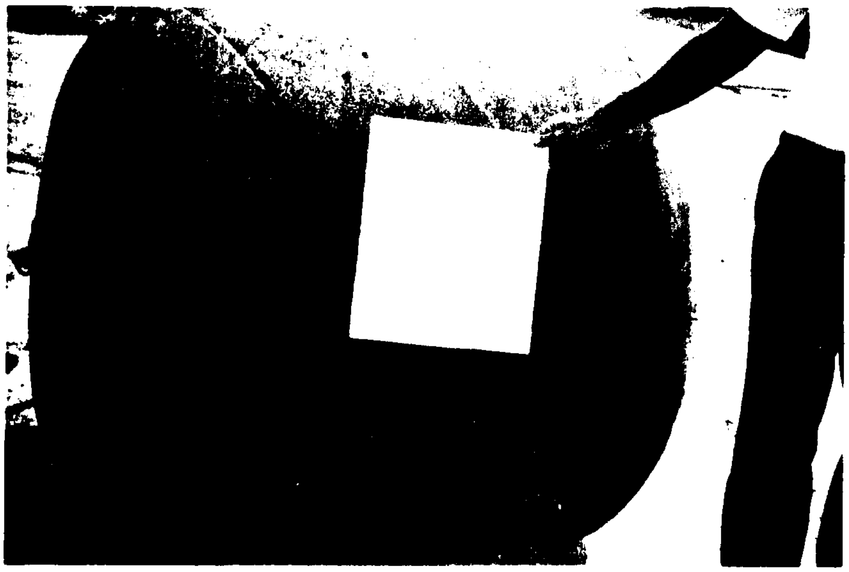


SN 5 AIR DROP DRUM AFTER 3RD IMPACT

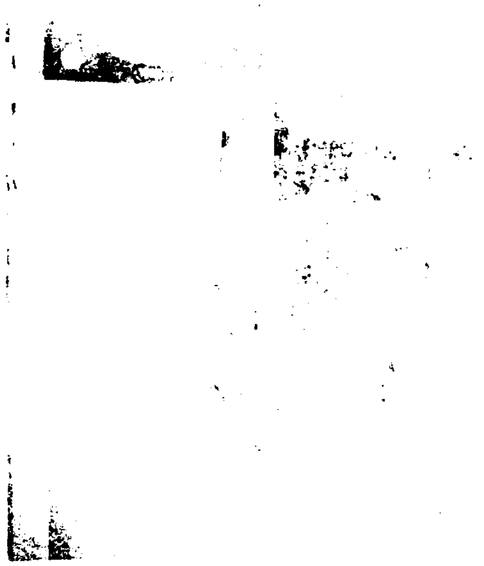
SN 8 ROLLING TOW MOUNTING ASSEMBLY

SN 8 ROLLING TOW AFTER 1 MILE

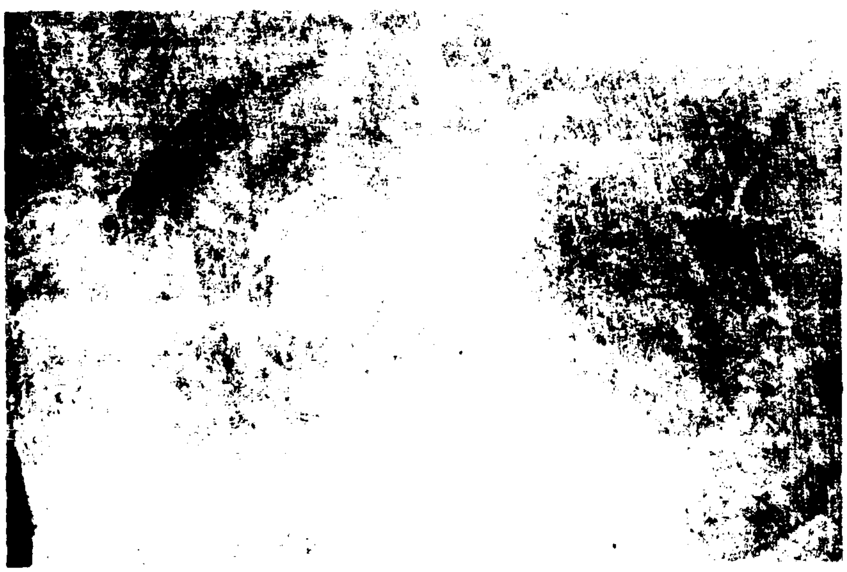
SN8 ROLLING TOW
AFTER 5 MILES



SN8 ROLLING TOW
AFTER 10 MILES



SN4 LOW TEMPERATURE
COLLAPSIBILITY
CHAMBER CONTROLS



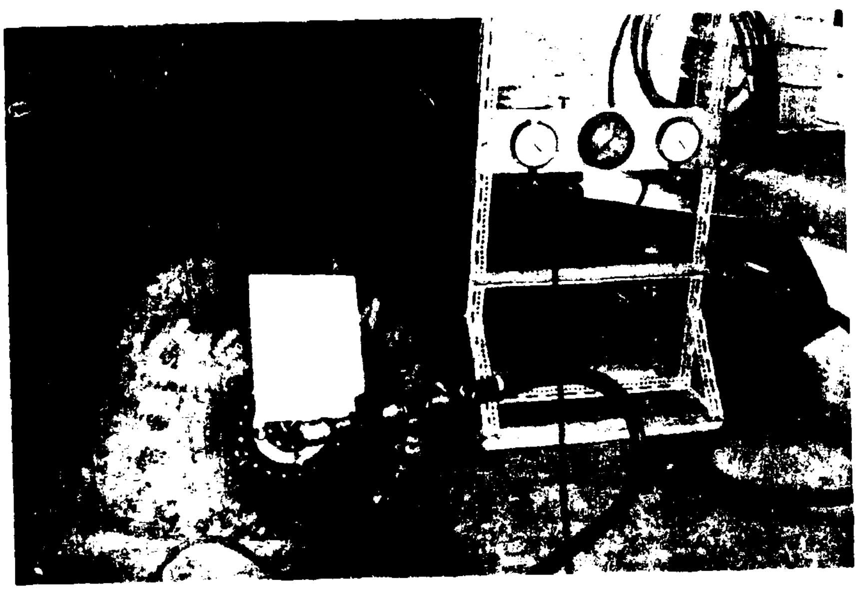
SN4 LOW
TEMPERATURE
COLLAPIBILITY
457.85 GAL. OF
465.00 GAL.
REMOVED
AT -60°F

SN4 LOW TEMPERATURE COLLAPSIBILITY AFTER FUEL REMOVAL AT -60°F.

SN4 LOW TEMPERATURE COLLAPSIBILITY AFTER FUEL REMOVAL AT -60°F.

SN4 BEING REFILLED WITH -60°F FUEL

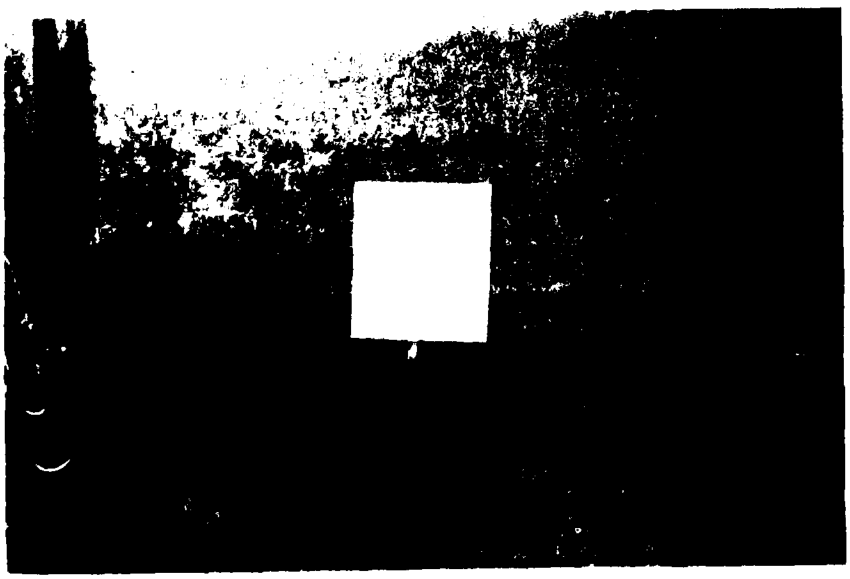
SN4 BEING REFILLED WITH -60°F. FUEL



SN8 AMBIENT TEMPERATURE COLLAPSIBILITY

"D" CONSTRUCTION HOSE PRESSURE TESTING

SN001
AT 300PSI



SN001
AT 300PSI

APPENDIX III

Test Method Developed To Test Cord Breaking Strength and Elongation

When tire cord is clamped between jaws in a tensile machine and tested to failure, the accuracy of the resulting load and strain data is generally questionable because of stress concentration at the clamping points and possible slippage within the jaws.

In an effort to obtain greater accuracy of these values, a cam jaw device was used as shown in page III-2. This device reduces stress concentration because the cord passes over a roll in the top and bottom clamp before it is clamped by the cam jaws.

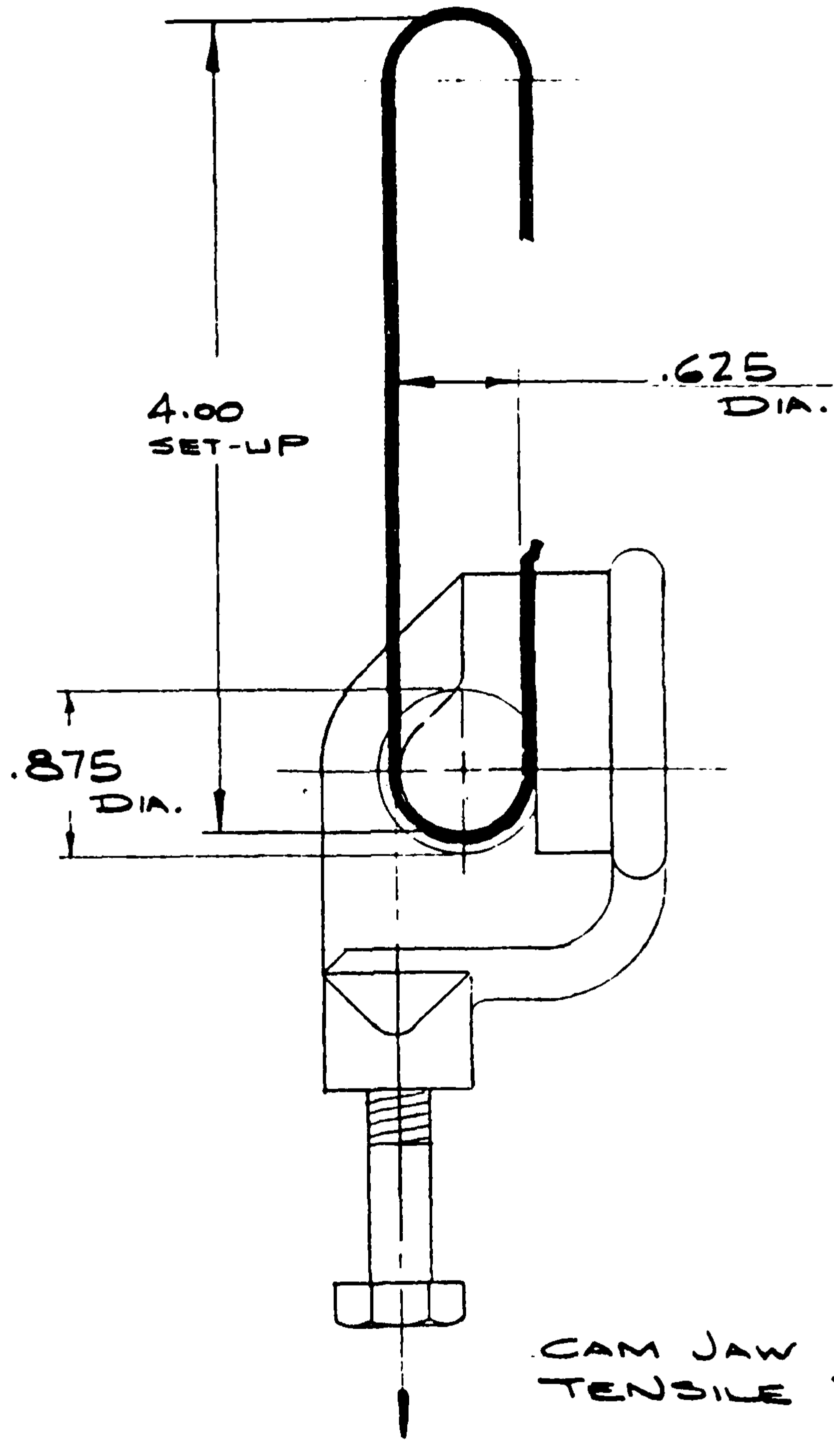
The tensile stress in the cord varies as the cord passes over the roll because of the friction between cord and roll in accordance with the following relationship:

$$\frac{{}^{*}T_2}{T_1} = e^{\mu_s \beta} \quad \ldots . \; (1)$$

Where T_1 and T_2 are the tensile values at each point increment of the cord as it passes over the roll and μ_s and β are the friction and angular contact of the cord on the roll surface.

By utilizing equation (1) the reduction in tension (and elongation) was established as a function of the angular contact area of the cord as it passes over the roll surface. The friction values μ_s were established by actual testing of each cord on the roll of the cam jaws. By utilizing this approach, it is felt that greater accuracy in tensile and elongation of the cord tested for this contract was achieved.

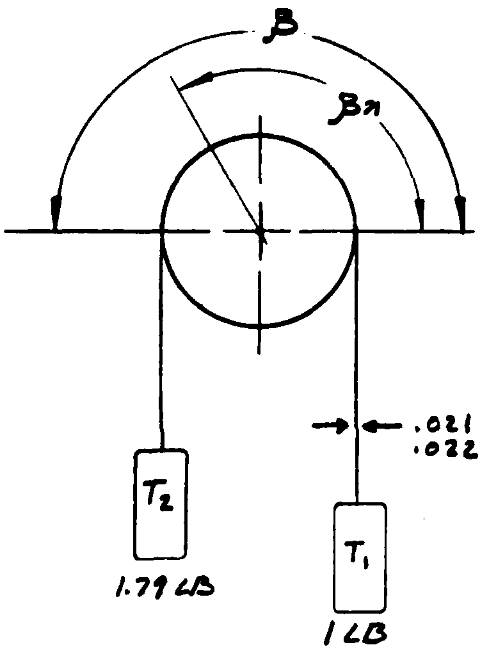
* Mechanics for Engineers Beer and Johnson



CAM JAW
TENSILE TEST

COEFFICIENT OF FRICTION AND ELONGATION

NYLON TIRE CORD
#315-77-324



$$\ln \frac{T_2}{T_1} = \mu_s \beta$$

$\beta = \pi$ RADIANS

$$\ln \frac{1.79}{1.0} = \mu_s \beta$$

$$\mu_s = .18535$$

$$T_2 = T_1 e^{\mu_s \beta}$$

β_n	β RADS	T_2	% ELONG.
180°	3.1416	1.79	100
135°	2.356	1.547	86.42
90°	1.5708	1.338	74.75
45°	.7854	1.1567	64.62
10°	.1745	1.033	57.71
0°	0	1.00	55.87

AVE = 73.23 %
ELONGATION
AROUND ROLL

APPENDIX IV

Relative Rigidity and Composite Modulus Calculations

Relative or flexural rigidity is a measure of the stiffness of a material or laminate. It is expressed mathematically as modulus of elasticity times moment of inertia or "EI".

Moment of inertia of an area with respect to an axis is the sum of the products obtained by multiplying each element of the area "dA" by the square of its distance from the axis "x". It is therefore the quantity $I_x = \int Y^2 \, dA$

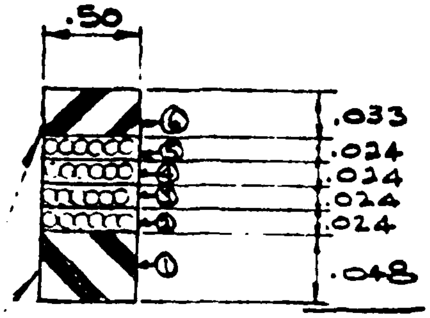
If the plane area consists of a laminate of several layers of varying thickness, the stiffness of the individual layers must be computed separately relative to the centroid of the mass.

The overall stiffness of the laminate is then the summation of individual component stiffnesses of the composite members relative to the mass centroid.

The calculations are shown on page IV-2 through IV-8, attached.

RELATIVE RIGIDITY & COMPOSITE MODULUS @ -60°F

4 PLY NYLON 840/2 (315-77-324)



TOTAL = 0.177

POLYPROPYLENE OXIDE
101910A

$$I = \frac{bh^3}{12} = \frac{(.5)(.177)^3}{12} = .0002310513 \text{ IN}^4$$

$$E_c I_c = \Sigma(\underset{\text{FABRIC}}{E_f I_f} + \underset{\text{POLYMER}}{E_P I_P})$$

	AREA	Y	AXY
1.	.024	.024	.000576
2.	.012	.06	.00072
3.	.012	.084	.001008
4.	.012	.108	.001296
5.	.012	.132	.001584
6.	.0165	.1605	.00264825
	.0885		.00783225

$\bar{Y} = .0885$ IN.

$$I_T = I_o + Ad^2$$

$$I_1 = .0000004608 + .024\,(\bar{Y} - .024)^2 = .000104454$$

$$I_2 = .000000576 + .012\,(\bar{Y} - .06)^2 = .00001 0323$$

$$I_3 = .000000576 + .012\,(\bar{Y} - .084)^2 = .000000819$$

$$I_4 = .000000576 + .012\,(.108 - \bar{Y})^2 = .000005139$$

$$I_5 = .000000576 + .012\,(.132 - \bar{Y})^2 = .000023283$$

$$I_6 = .0000014973 + .0165\,(.1605 - \bar{Y})^2 = .0000870333$$

$$I_T = .0002310513 \text{ IN}^4$$

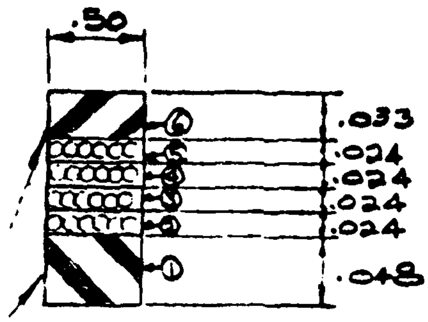
$E_{FABRIC} = 418{,}365$ $\quad E_P = 4{,}700$ $\quad I_f = I_2 + \cdots + I_5$, $I_P = I_1 + I_6$

$I_f = .000039564$, $I_P = .0001914873$

$$E_c I_c = (418{,}365)(.000039564) + (4700)(.0001914873) = 17.452 \text{ LBS-IN}^2$$

RELATIVE RIGIDITY & COMPOSITE MODULUS @ -60°F

4 PLY POLYESTER 1000/2 (315-23-122)



TOTAL = 0.177

$$I = \frac{bh^3}{12} = \frac{(.5)(.177)^3}{12} = .0002310513 \text{ IN}^4$$

$$E_c I_c = \Sigma(E_f I_f + E_P I_P)$$

FABRIC POLYMER

POLYPROPYLENE OXIDE

#101910A

	AREA	Y	AXY
1.	.024	.024	.000576
2.	.012	.06	.00072
3.	.012	.084	.001008
4.	.012	.108	.001296
5.	.012	.132	.001584
6.	.0165	.1605	.00264825
	.0885		.00783225

$\bar{y} = .0885$

$$I_T = I_o + Ad^2$$

$$I_1 = .000004608 + .024(\bar{y} - .024)^2 = .000104454$$

$$I_2 = .000000576 + .012(\bar{y} - .06)^2 = .000010323$$

$$I_3 = .000000576 + .012(\bar{y} - .084)^2 = .000000819$$

$$I_4 = .000000576 + .012(\bar{y} - .108)^2 = .000005139$$

$$I_5 = .000000576 + .012(\bar{y} - .132)^2 = .000023283$$

$$I_6 = .000001497 + .0165(\bar{y} - .1605)^2 = .000087033$$

$$I_T = .000231051$$

$E_{fabric} = 518{,}619$ $E_P = 4700$ $I_f = I_2 + \cdots + I_5$, $I_P = I_1 + I_6$

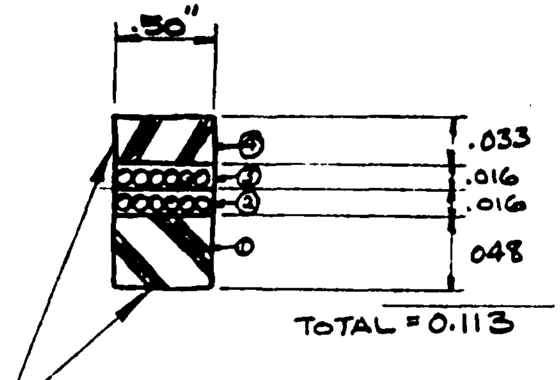
$I_f = .000039564$, $I_P = .000191487$

$$E_c I_c = 518{,}619(.000039564) + 4700(.000191487) = 21.418$$

LBS-IN²

RELATIVE RIGIDITY & COMPOSITE MODULUS @ -60°F

2 PLY KEVLAR 1500/1 3TPI



POLYPROPYLENE OXIDE
#101510A

$$I = \frac{bh^3}{12} = \frac{(.5)(.113)^3}{12} = .0000601207 \text{ IN}^4$$

$$E_c I_c = \sum \left(E_f I_f + E_p I_p \right)$$

FABRIC POLYMER

	AREA	Y	A x Y
1.	.024	.024	.000576
2.	.008	.056	.000448
3.	.008	.072	.000576
4.	.0165	.0965	.00159225
	.0565	TOTAL	.00319225

$Y = .0565$

$$I_T = I_o + Ad^2$$

$$I_1 = .000004608 + .024\,(\bar{Y} - .024)^2 = .000029958$$

$$I_2 = .0000001706 + .008\,(.0560 - \bar{Y})^2 = .0000001726$$

$$I_3 = .0000001706 + .008\,(.072 - \bar{Y})^2 = .0000020926$$

$$I_4 = .0000014973 + .0165\,(.0965 - \bar{Y})^2 = .0000278973$$

$$I_T = .0000601205 \text{ IN}^4$$

$E_{FABRIC} = 10{,}839{,}285$, $E_p = 4700$, $I_f = I_2 + I_3$, $I_p = I_1 + I_4$

$$I_p = I_1 + I_4 = .000029958 + .0000278973 = .0000578553 \text{ IN}^4$$

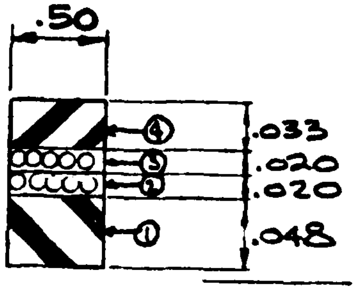
$$I_f = I_2 + I_3 = .0000001726 + .0000020926 = .0000022652 \text{ IN}^4$$

$$E_c I_c = (10{,}839{,}285)(.0000022652) + (4700)(.0000578553) = 24.825$$

LBS-IN2

RELATIVE RIGIDITY & COMPOSITE MODULUS @ -60°F

2 PLY KEVLAR 1500/2 3TPI



TOTAL = .121

$$I = \frac{bh^3}{12} = \frac{(.5)(.121)^3}{12} = .000073815$$

$$E_c I_c = \sum (\underbrace{E_f I_f}_{\text{FABRIC}} + \underbrace{E_P I_P}_{\text{POLYMER}})$$

POLYPROPYLENE OXIDE
#101910A

	AREA	Y	A×Y
1.	.024	.024	.000576
2.	.01	.058	.00058
3.	.01	.078	.00078
4.	.0165	.1045	.00172425
	.0605		.00366025

$\bar{Y} = .0605$

$$I_T = I_o + Ad^2$$

$$I_1 = .000004608 + .024(\bar{y} - .024)^2 = .000036582$$

$$I_2 = .0000003333 + .01(\bar{y} - .058)^2 = .0000003958$$

$$I_3 = .0000003333 + .01(.078 - \bar{y})^2 = .0000033958$$

$$I_4 = .0000014973 + .0165(.1045 - \bar{y})^2 = .0000334413$$

$$I_T = .0000738149 \text{ IN}^4$$

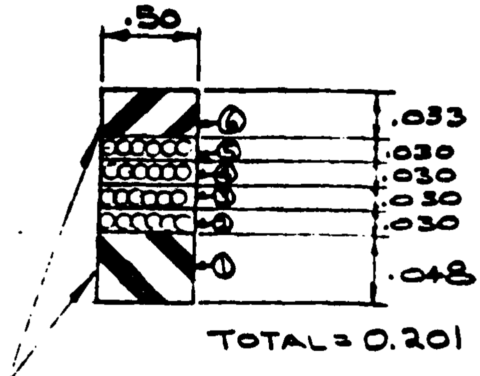
$E_{FABRIC} = 6{,}645{,}161$ $\quad$ $E_P = 4700$ $\quad$ $I_f = I_2 + I_3$, $I_P = I_1 + I_4$

$I_f = .0000037916$, $\quad$ $I_P = .0000700233$

$$E_c I_c = (6{,}645{,}161)(.0000037916) + (4700)(.0000700233) = 25.525 \text{ LBS-IN}^2$$

RELATIVE RIGIDITY & COMPOSITE MODULUS @ -60°F

4 PLY RAYON 1650/2 (315-26-916)



$$I = \frac{bh^3}{12} = \frac{(.5)(.201)^3}{12} = .000338358$$

$$E_c I_c = \Sigma(\underset{\text{FABRIC}}{E_f I_f} + \underset{\text{POLYMER}}{E_p I_p})$$

POLYPROPYLENE OXIDE

#101910A

	AREA	Y	AXY
1.	.024	.024	.000576
2.	.015	.063	.000945
3.	.015	.093	.001395
4.	.015	.123	.001845
5.	.015	.153	.002295
6.	.0165	.1845	.00304425
	.1005		.01010025

$\bar{Y} = .1005$

$I_T = I_o + Ad^2$

$I_1 = .000004608 \quad + .024\ (\bar{Y} - .024)^2 = .000145062$

$I_2 = .000001125 \quad + .015\ (\bar{Y} - .063)^2 = .000022219$

$I_3 = .000001125 \quad + .015\ (\bar{Y} - .093)^2 = .000001969$

$I_4 = .000001125 \quad + .015\ (\bar{Y} - .123)^2 = .000008719$

$I_5 = .000001125 \quad + .015\ (.153 - \bar{Y})^2 = .000042469$

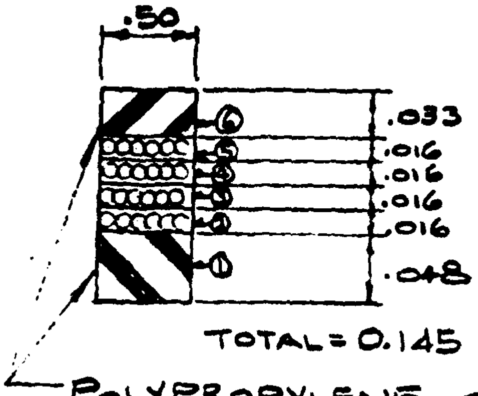
$I_6 = .0000014973 \quad + .0165\ (.1845 - \bar{Y})^2 = .000117921$

$I_T = .000338359$

$E_{fabric} = 322{,}655 \quad E_p = 4700 \qquad I_f = I_2 + \dots + I_5\ ,\ I_p = I_1 + I_6$

$I_f = .000075376 \qquad , I_p = .000262983$

$E_c I_c = (322{,}655)(.000075376) + (4700)(.000262983) = 25.556$ LBS-IN²



RELATIVE RIGIDITY & COMPOSITE MODULUS @ -60°F

4 PLY KEVLAR 1500/1 3TPI

$$I = \frac{bh^3}{12} = \frac{(.5)(.145)^3}{12} = .000127026$$

$$E_c I_c = \Sigma(\underset{\text{FABRIC}}{E_f I_f} + \underset{\text{POLYMER}}{E_P I_P})$$

POLYPROPYLENE OXIDE

#101910A

	AREA	Y	AXY
1.	.024	.024	.000576
2.	.008	.056	.000448
3.	.008	.072	.000576
4.	.008	.088	.000704
5.	.008	.104	.000832
6.	.0165	.1285	.00212025
	.0725		.00525625

$\bar{Y} = .0725$

$I_T = I_o + Ad^2$

$I_1 = .000004608 \quad + .024(\bar{Y} - .024)^2 = .000061062$

$I_2 = .0000001706 \quad + .008(\bar{Y} - .056)^2 = .000002349$

$I_3 = .0000001706 \quad + .008(\bar{Y} - .072)^2 = .000000173$

$I_4 = .0000001706 \quad + .008(.088 - \bar{Y})^2 = .000002093$

$I_5 = .0000001706 \quad + .008(.104 - \bar{Y})^2 = .000008109$

$I_6 = .0000014973 \quad + .0165(.1285 - \bar{Y})^2 = .000053241$

$I_T = .000127027$

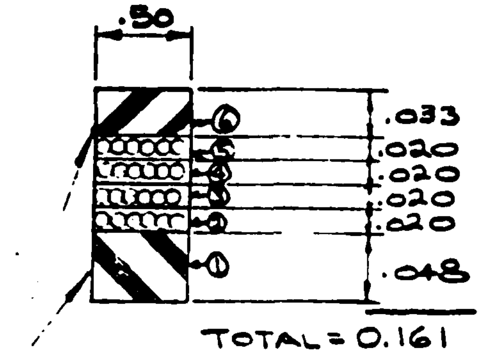
$E_{fabric} = 10,839,285 \quad E_P = 4700 \quad I_f = I_2 + \cdots + I_5 \;, \; I_P = I_1 + I_6$

$I_f = .000012724 \quad , \; I_P = .000114303$

$E_c I_c = (10,839,285)(.000012724) + (4700)(.000114303) = 138.456$ LBS - IN^2

RELATIVE RIGIDITY & COMPOSITE MODULUS @ -60^{0}F

4 PLY KEVLAR 1500/2 3TPI



POLYPROPYLENE OXIDE
#101910A

$$I = \frac{bh^3}{12} = \frac{(.5)(.161)^3}{12} = .0001738867$$

$$E_c I_c = \Sigma(E_f I_f + E_P I_P)$$

FABRIC POLYMER

	AREA	Y	AXY
1.	.024	.024	.000576
2.	.01	.058	.00058
3.	.01	.078	.00078
4.	.01	.098	.00098
5.	.01	.118	.00118
6.	.0165	.1445	.00238425
	.0805		.00648025

$\bar{Y} = .0805$

$$I_T = I_o + Ad^2$$

$$I_1 = .000004608 + .024\,(\bar{Y} - .024)^2 = .000081222$$

$$I_2 = .0000003333 + .01\,(\bar{Y} - .058)^2 = .0000053958$$

$$I_3 = .0000003333 + .01\,(\bar{Y} - .078)^2 = .0000003958$$

$$I_4 = .0000003333 + .01\,(.098 - \bar{Y})^2 = .0000033958$$

$$I_5 = .0000003333 + .01\,(.118 - \bar{Y})^2 = .0000143958$$

$$I_6 = .0000014973 + .0165\,(.1445 - \bar{Y})^2 = .0000690813$$

$$I_T = .0001738865$$

$E_{fabric} = 6{,}645{,}161$ $\quad E_P = 4700 \quad I_f = I_2 + \dots + I_5$, $I_P = I_1 + I_6$

$I_f = .0000235832$, $I_P = .0001503033$

$$E_c I_c = (6{,}645{,}161)(.0000235832) + 4700(.0001503033) = 157.42$$

APPENDIX V

List of Suppliers

Ingredient	Supplier
Parel 58	Hercules, Inc.
Adiprene CM	E. I. DuPont DeNemours & Co.
Polysulfide FA Polysulfide ST	Thiokol Corp.
Millathane 76 Millathane 100	Technical Sales and Engineering
Silastic LS 422	Dow Corning Corp.
Neoprene W	E. I. DuPont DeNemours & Co.
Protox 166	New Jersey Zinc Corp.
Maglite D	C. P. Hall
END 75	Wyrough and Loser
Curathane Activator 2013P	Technical Sales and Engineering Co., Inc.
Catur #4	E. I. DuPont DeNemours & Co.
Cadmium Stearate #22	Witco Chemical Co.
Plasticizer TP90B Plasticizer TP95	C. P. Hall
Plasticizer SC	Harwick Std.
Calcium Hydroxide	Fisher Scientific
Zinc Peroxide	FMC Corp. Becco Division
Cabosil MS-7	Schenectady Resin Corp.
Dicup 40C	Hercules Corp.
Chemlok TS2394-75	Lord Chemical Corp.
Polyester Tire Cord Nylon Tire Cord Rayon Tire Cord	Uniroyal, Inc. Textile Div.
Kevlar Tire Cord	E. I. DuPont DeNemours & Co.
Bally Mills Tape	Bally Ribbon Mills

END

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